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# AMERICAN CHEMICAL INDUSTRY

*THE MERGER ERA*

By  
WILLIAMS HAYNES

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VOLUME IV



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# CONTENTS

	<i>Page</i>
INTRODUCTION . . . . .	xv
CHEMICAL CHRONOLOGY . . . . .	xxi

## PART ONE: THE BOOMING TWENTIES

### *Chapter*

1. THE RETURN TO NORMALCY . . . . .	3
BOOMING AUTOMOBILE, MOTION PICTURES, AND RADIO INDUSTRIES CREATE NEW CHEMICAL DEMANDS—COOLIDGE ADMINISTRATION COOPERATES WITH INDUSTRY; REDUCES PUBLIC DEBT AND TAXES—SECRETARY OF COMMERCE HOOVER URGES COLLECTION OF STATISTICAL DATA AND APPOINTS CHEMICAL ADVISORY COMMITTEE—ANTIDUMPING AND FLEXIBLE PROVISIONS OF 1922 TARIFF UPHELD IN COURT, BUT AMERICAN VALUATION FAILS.	
2. THE STATE OF TRADE . . . . .	17
CHEMICALS PASS WARTIME PRODUCTION LEVELS—NEW CHEMICAL PRODUCTS COMPETE WITH OLD AS MASS PRODUCTION METHODS ARE PERFECTED—PRICE CUTTING AND "PROTECTION-AGAINST-DECLINE" IN SALES CONTRACTS DEMORALIZE MARKET—COMPETITION FORCES REVISED SELLING ORGANIZATIONS, IMPROVED ADVERTISING, AND TECHNICAL SALES SERVICE—CHEMICAL EXPANSION SOUTHWARD AND WESTWARD.	
3. AMERICAN CHEMICAL MERGERS . . . . .	31
CAUSES OF WORLD-WIDE CHEMICAL CONSOLIDATIONS DURING TWENTIES; DIVERSIFICATION CHIEF AMERICAN AIM—DU PONT BUYS GRASSELLI—ALLIED CONCENTRATES ON PRODUCERS' CHEMICALS, UNION CARBIDE ON CONSUMERS'—MONSANTO STRENGTHENS HEAVY CHEMICAL LINE THROUGH MERRIMAC—AMERICAN CYANAMID BUYS CALCO AND KLIPSTEIN, ACHIEVING 4TH PLACE IN INDUSTRY—OVER 500 CHEMICAL MERGERS IN U. S.	
4. FOREIGN CARTELS AND TRUSTS . . . . .	48
RATIONALIZATION MOVEMENT IN EUROPE—CHEMICAL PRODUCERS BAND IN TRUSTS AND INTERNATIONAL CARTELS—CONTROL OF NATIONAL CHEMICAL PRODUCTION IN GERMANY, ENGLAND, FRANCE, AND ITALY IN HANDS OF I.G., I.C.I., KUHLMANN, AND MONTECATINI—GENEVA ECONOMIC CONFERENCE ATTACKS HIGH TARIFFS, ESPECIALLY AMERICAN, AND EVADES CARTEL QUESTION—INTERNATIONAL CHAMBER OF COMMERCE INEFFECTUAL.	

## PART TWO: INORGANIC CHEMICALS

5. CONTACT ACID FROM BRIMSTONE . . . . .	67
CONTACT PROCESS SUPERSEDES CHAMBER AS MONSANTO, SELDEN, AND GENERAL CHEMICAL PROMOTE VANADIUM CATALYSTS FOR HIGH-TEST ACID—BRIMSTONE OUTPUT DOUBLES WAR RECORD—NEW GULF COAST SULFUR DOMES TAPPED: HOSKINS BY FREEPORT, PALANGANA BY DUVAL, BOLING BY TEXAS GULF—SULEXCO-SICILIAN CONSORTIUM AGREEMENT STABILIZES WORLD MARKET—BY-PRODUCT SULFUR SOURCES COMMERCIALIZED—RIO TINTO RE-ENTERS AMERICAN PYRITES MARKET.	

Chapter	Page
6. NITRIC ACID FROM AMMONIA . . . . .	85
SYNTHETIC U. S. BY-PRODUCT AMMONIA COMPETITION HALVES PRICE, BENEFIT- ING ALL CONSUMING INDUSTRIES—ATMOSPHERIC NITROGEN BUILDS LARGEST AMERICAN AIR-NITROGEN PLANT—DU PONT BUYS AMERICAN RIGHTS TO CLAUDE AND CASALE PROCESSES, ORGANIZES LAZOTE—SHELL ON WEST COAST WORKS MONT CENIS PROCESS—NITROGEN ENGINEERING BUILDS PLANTS ABROAD—WIDE- SPREAD AMERICAN ADOPTION OF OSTWALD PROCESS FOR NITRIC ACID, WITH IM- PROVEMENTS IN CATALYSTS, GASES, AND APPARATUS.	
7. PHOSPHORUS COMPOUNDS . . . . .	96
FLOTATION ADOPTED IN PHOSPHATE MINING—MOROCCO CAPTURES EUROPEAN MARKET FROM U. S.—DOMESTIC ROCK EXPANDS IN PHOSPHATES FOR BAKING POWDER AND INDUSTRIAL CHEMICALS—SWANN CAMPAIGNS FOR CONCENTRATED FERTILIZERS; SELLS ELECTROTHERMAL PROCESS ABROAD, BUILDS FRENCH PLANT— VICTOR MAKES HIGH-TEST PHOSPHORIC ACID IN BLAST FURNACE—LILJENROTH IMPROVEMENT IN WET PROCESS ACQUIRED BY DU PONT—PHOSPHATES ADVANCE IN SUGAR REFINING, RUSTPROOFING, PLASTICIZERS.	
8. ELECTROLYTIC COMPETITION IN ALKALIES . . . . .	111
ALKALI OUTPUT EXCEEDS WARTIME RECORDS—AMMONIA-SODA COMPANIES ADOPT ELECTROLYTIC PROCESS—ALKALI PRODUCERS UNDERTAKE OWN SALES— NATURAL SODA REVIVES ON SOUNDER BASIS—CHLORINE DISPLACES BLEACHING POWDER AS PRICE DROPS TO 3½¢—ELECTROLYTIC PLANTS IMPROVE CELL DESIGN, ADD NEW SALTS AND CHLORINE DERIVATIVES—WESTVACO BUYS WARNER AND FORMS UNITED CHEMICALS—EASTERN FIRMS BUILD WESTERN ELECTROLYTIC PLANTS—CHLORINE INSTITUTE FORMED.	
9. OTHER INDUSTRIAL CHEMICALS . . . . .	127
SYNTHETIC PRODUCTS UPSET <i>status quo</i> —SALT CAKE IN PRIMARY PRODUCTION— GREATER OUTPUT OF SODIUM SALTS FOLLOWS NEW USES—CHEAP ALUMINUM CHLORIDE IN PETROLEUM REFINING—BARIUM PIGMENTS FORCE REORGANIZATION IN BARYTES—DOW PERSEVERES IN MAGNESIUM FROM BRINE—MAGNESITE RECOV- ERS FROM FOREIGN DUMPING—CHROME PLATING MAKES CHROMIC ACID AN IN- DUSTRIAL CHEMICAL—ALUMINUM COMPANY PRODUCES ARTIFICIAL CRYOLITE	

### PART THREE: ORGANIC CHEMICALS

10. ALCOHOL UNDER PROHIBITION . . . . .	151
INDUSTRIAL ALCOHOL SUFFERS UNDER ARBITRARY ENFORCEMENT AND CHANGES IN DENATURED FORMULAS—AGITATION AGAINST POISONOUS METHANOL: ALDE- HOL OBLIGATORY IN CD FORMULAS AND HARMLESS DENATURANTS SOUGHT— DORAN REPLACES HAYNES IN NEW PROHIBITION BUREAU—SWITCH TO MOLASSES CLOSES MANY MIDWEST DISTILLERS AND MERGERS CONCENTRATE OUTPUT IN U.S.I., AMERICAN SOLVENTS, AND AMERICAN COMMERCIAL ALCOHOL COMPANIES —SYNTHETIC ALCOHOL AND NEW SOLVENTS INVADE THE INDUSTRY.	
11. WOOD CHEMICALS MEET SYNTHETIC COMPETITION . . . . .	169
GERMAN SYNTHETIC METHANOL AT 45¢ A GALLON COUNTERED BY HIGHER DUTY; USE OF NATURAL METHANOL IN DENATURED ALCOHOL; FEWER, BIGGER PLANTS; NEW TECHNICAL AND SALES METHODS—DOMESTIC SYNTHETIC OUTPUT FROM COMMERCIAL SOLVENTS AND DU PONT—BREWSTER AND SUIDA PROCESSES ADOPTED TO COMPETE WITH SYNTHETIC ACETIC ACID—WOOD CHEMICAL INSTI- TUTE UNDERTAKES EDUCATION AND RESEARCH.	

<i>Chapter</i>	<i>Page</i>
12. SOLVENTS LEAD ORGANIC PROGRESS . . . . .	187
<p>FERMENTATION BUTANOL AND ACETATE COMPETE WITH SYNTHETIC BUTYL AND AMYL SOLVENTS FOR NEW LACQUER MARKET—AN ALIPHATIC INDUSTRY BASED ON PETROLEUM AND NATURAL GAS PIONEERED BY STANDARD OIL, CARBIDE AND CARBON: ISOPROPANOL, METHYL ETHYL KETONE, GLYCOLS, ETHANOLAMINES, CHLORINATED SOLVENTS—COMMERCIAL SOLVENTS MAKES ALCOHOLS FROM WASTE GASES—SHARPLES SOLVENTS CHLORINATES PENTANES—SOLVENTS INSTITUTE FORMED.</p>	
13. CRUDES AND INTERMEDIATES . . . . .	207
<p>COAL-TAR CHEMICALS MOVE INTO NEW, BIG-TONNAGE FIELDS—STEEL COMPANIES RECOVER OWN CRUDES, OLDER DISTILLERS EXPAND—INTERNATIONAL COMBUSTION BUILDS LOW-TEMPERATURE CARBONIZATION PLANT—TOXICITY OF BENZENE STUDIED—DOW MAKES PHENOL FROM CHLOROBENZENE—DUTY ON PHENOL AND CRESYLIC ACID CUT—NEW METHODS AND DERIVATIVES FOR ANTHRAQUINONE, ANILINE, NAPHTHIALENE, DIPHENYL—MORE INTERMEDIATES, WITH GREATER OUTPUT AND FEWER PRODUCERS.</p>	
14. AMERICAN DYES BUILD A FIRM BASE . . . . .	227
<p>KEEN COMPETITION FORCES REVISION OF PROCESSES AND DEVELOPMENT OF NEW COLORS; ENCOURAGES MERGERS—SMALLER MAKERS SPECIALIZE—I.G. SALES CONCENTRATED IN GENERAL DYESTUFF, PRODUCTION IN GENERAL ANILINE—DEALERS REORGANIZE—STANDARDS DEVELOPED BY COLOR LABORATORY—IMPORTS ASSESSED ON STRENGTH—CHEMICAL FOUNDATION AGAIN VINDICATED IN COURT.</p>	

#### PART FOUR: MEDICINAL AND OTHER FINE CHEMICALS

15. COAL-TAR MEDICINAL CHEMICALS . . . . .	245
<p>OFFICIAL RECOGNITION OF SYNTHETIC MEDICINALS—AMERICAN NAMES ADOPTED AS OUTPUTS SOAR—NEW BARBITURATES MARKETED; DUTY BASED ON U. S. SELLING PRICE—RESEARCH IN ARSENICALS, MERCURIALS, NEW ANTISEPTICS: TRYPARSAMIDE, MERCUROCHROME, HEXYLRESORCINOL—UNIVERSITY FELLOWSHIPS SPONSORED BY MANUFACTURERS—FIRMS WITH GERMAN CONNECTIONS REORGANIZE: HEYDEN, LEHN &amp; FINK—DYEMAKERS MAKE MEDICINALS.</p>	
16. THE FINE CHEMICALS . . . . .	257
<p>POWERS-WEIGHTMAN-ROSENGARTEN AND MERCK MERGER—ETHYL GASOLINE MAKES BROMINE BIG-TONNAGE CHEMICAL—OIL AND SALT WELLS WORKED FOR HALOGENS—CHLORINE AND IODINE TESTED MEDICINALLY; ANESTHETICS IMPROVED; NEW ALDEHYDES, ALCOHOLS, ESTERS PRODUCED—PFIZER FERMENTATION CITRIC ACID SPURS PACIFIC CITRUS BY-PRODUCTS RECOVERY—NEW TECHNIQUES, NEW USES, HIGHER DUTIES CHECK FOREIGN MONOPOLIES OF MEDICINAL RAW MATERIALS.</p>	
17. DRUG PRODUCTS AND PHARMACEUTICALS . . . . .	274
<p>BRANDED GOODS, PRICE CUTTING, SUBSTITUTION, DISTRIBUTION RAISE NEW PROBLEMS—DRUG REGULATIONS TIGHTENED; "MULTIPLE SEIZURES"—FOOD, DRUG &amp; INSECTICIDE ADMINISTRATION SET UP—STRICTER NARCOTIC CONTROLS—U. S. FIGHTS DUTCH QUININE CARTEL—EPHEDRINE INTRODUCED; CAFFEINE FROM THEOBROMINE—RESEARCHES FOR MALARIA, LEPROSY, HEART DISEASE, COLD REMEDIES—ALKALOID PRICES DROP—MERGERS PROMINENT IN PROPRIETARY FIELD.</p>	

<i>Chapter</i>	<i>Page</i>
<b>18. SCENTS AND FLAVORS: SYNTHETIC AND NATURAL .</b>	<b>294</b>
COSMETIC PRODUCTION REACHES 194 MILLION DOLLARS—HIGHER DUTIES ON AROMATIC CHEMICALS THAN ON AROMATIC MIXTURES HAMPER U. S. MANUFACTURE—CAMPAIGN FOR AMERICAN TOILET GOODS—MONOPOLIES IN MENTHOL, CAMPHOR, AND MUSKS CURBED BY SYNTHETIC PRODUCTS—SACCHARIN APPROVED IN FOODSTUFFS—VANILLIN AND COUMARIN ADVANCE AS FLAVORS—VAN AMERINGEN-HAEBLER AND COLGATE-PALMOLIVE-PEET MERGERS.	
 <b>PART FIVE: THE CONSUMING INDUSTRIES</b>	
<b>19. FERTILIZERS . . . . .</b>	<b>311</b>
CHILFAN ECONOMY UPSET BY AIR NITROGEN; WORLD NITRATE PRODUCERS FORM CARTEL—ANGLO-CHILEAN WORKS GUGGENHEIM PROCESS—AMMONIATED SUPERPHOSPHATE, UREA, OTHER CHEMICAL INGREDIENTS ENCOURAGE CONCENTRATED FERTILIZERS—BATTLE OVER MUSCLE SHOALS—GERMAN-ALSACE POTASH SALES AGENCY IN U. S. DISSOLVED—SEARLES LAKE IN PRODUCTION AND POTASH FOUND IN PERMIAN BASIN—DEMORALIZED FERTILIZER INDUSTRY WRITES CODE OF ETHICS, MERGES ASSOCIATIONS.	
<b>20. NEW PEST-CONTROL CHEMICALS . . . . .</b>	<b>332</b>
NEW ORGANIC CHEMICALS TESTED AS INSECTICIDES, FUNGICIDES, FUMIGANTS, AND SEED DISINFECTANTS—CAMPAIGN AGAINST BOLL WEEVIL, GYPSY MOTH, ETC., WITH ARSENICALS AND FLUOSILICATES—INTERNATIONAL COPPER WAR WEAKENS U. S. FUNGICIDE MARKET—BELGIAN CONGO BECOMES WORLD COPPER HEADQUARTERS—HYDROCYANIC FUMIGATION IN CITRUS INDUSTRY—UNBALANCED SUPPLY AND DEMAND HARASSES INSECTICIDE MAKERS; MERCHANDISING IMPROVED, PACKAGING SIMPLIFIED.	
<b>21. FROM PLASTICS TO RESINS . . . . .</b>	<b>348</b>
SYNTHETIC LACQUERS AND RESINS OPEN NEW OUTLETS FOR COAL-TAR INTERMEDIATES AND SOLVENTS—PHENOLIC PLASTICS MULTIPLY; FURFURAL PLASTICS PRODUCED—DU PONT ACQUIRES CELLOPHANE RIGHTS; CELANESE ABSORBS CELLULOID—CASEIN PLASTICS PERFECTED; ACRYLATE, UREA, STYROL RESINS APPEAR—OIL-SOLUBLE PHENOLIC AND ALKYD RESINS DEVELOPED TO COMPETE WITH NITROCELLULOSE LACQUERS—LACQUER INSTITUTE FORMED.	
<b>22. OILS AND PIGMENTS . . . . .</b>	<b>363</b>
PAINT INDUSTRY AWAKENED BY SYNTHETIC LACQUERS—TUNG OIL BOOM IN SOUTH—TITANIUM PIGMENTS BECOME TONNAGE ITEMS—PROGRESS IN ZINC PIGMENTS; LIGHT-RESISTANT LITHOPONE MADE—LEAD INDUSTRY MAINTAINED AS PRODUCTS MOVE INTO NON-PIGMENT FIELDS—MERGERS PROMINENT AMONG PIGMENT MAKERS—COLOR APPLIED IN CONSUMER GOODS; PAINT MATERIALS STANDARDIZED; RESEARCH PROMOTED.	
<b>23. RAYON AND OTHER TEXTILES . . . . .</b>	<b>376</b>
CHEMICAL SURPLUSES CONSUMED AS RAYON OUTPUT INCREASES 15-FOLD WITHIN DECADE—TEXTILE INDUSTRY RELINQUISHES OWN RAYON PRODUCTION—THREE BIG FOREIGN MAKERS ENTER AMERICAN FIELD GRAVITATING SOUTHWARDS—ACETATE RAYON COMPETES WITH VISCOSE, CUPRAMMONIUM REVIVED—RAYON MAKERS SWITCH FROM COTTON LINTERS TO WOOD PULP CELLULOSE; EXPLORE FARM WASTES—RAYON TRADE ASSOCIATION ORGANIZED; STUDIES STANDARDS AND SPECIFICATIONS.	

<i>Chapter</i>	<i>Page</i>
24. PETROLEUM AND TETRAETHYL LEAD . . . . .	390
THERMAL CRACKING BECOMES STANDARD REFINERY PRACTICE—ROCKEFELLER AND UNIVERSAL OIL SUBSIDIZE FUNDAMENTAL RESEARCH—CHEMICAL INTEREST ENCOURAGED BY CATALYTIC CRACKING, HYDROGENATION, SOLVENT DEWAXING—CHEMICALS FROM GAS AND OIL DEVELOPED BY CARBIDE AND CARBON, AND SHARPLES—GENERAL MOTORS PERFECTS TETRAETHYL LEAD ANTI-KNOCK ADDITIVE—ADVANCES IN NATURAL GASLINE TECHNIQUE—"BOTTLED GAS" GROWS RAPIDLY.	
25. CHEMICALS IN INDUSTRY . . . . .	408
MECHANICAL INDUSTRIES ADOPT CHEMICAL METHODS AND MATERIALS—IMPROVED ACCELERATORS, NEW ANTIOXIDANTS, USE OF LATEX ADVANCE RUBBER COMPOUNDING—CARBON BLACK PRODUCERS MOVING WESTWARD—MIXED FIBERS CREATE NEW FABRICS—SOUTHERN AND NORTHWESTERN EXPANSION OF PAPER PRODUCTION—GLASS AND CERAMICS, TANNING, REFRIGERATION, AND FOODSTUFFS COME UNDER NEW CHEMICAL INFLUENCES.	
26. BROADENING CHEMICAL BOUNDARIES . . . . .	429
NEW RAW MATERIALS, TONNAGE SYNTHETICS, NEW USES EXPAND CHEMICAL INDUSTRY—NATIONAL RESEARCH COUNCIL LEADS COOPERATIVE ACADEMIC-INDUSTRIAL RESEARCH—WILLIAMSTOWN SYMPOSIUM ON CHEMISTRY IN WORLD AFFAIRS—AMERICAN CHEMICAL SOCIETY SPONSORS INSTITUTE OF CHEMISTRY—GIFTS FURTHER CHEMICAL EDUCATION, BUILD UNIVERSITY LABORATORIES—AMERICAN INSTITUTE OF CHEMISTS AND ASSOCIATION OF CONSULTING CHEMISTS & CHEMICAL ENGINEERS ORGANIZED—CHEMICAL EXPOSITION AND CHEMICAL TRADE PAPERS REVAMPED.	
APPENDIX	
I. Tariff Rates on Chemicals and Their Raw Materials, 1930 . . . . .	441
II. Census of Value of U. S. Chemicals and Allied Products, 1923-29 . . . . .	449
III. Census of U. S. Chemical Industry . . . . .	450
IV. Price List of Important Representative Chemicals and Related Products, 1922-29 . . . . .	451
V. U. S. Imports of Drugs, Chemicals, and Their Products, 1923-29 . . . . .	467
VI. U. S. Exports of Drugs, Chemicals, and Their Products, 1923-29 . . . . .	495
VII. Report of the Joint Committee on Uniform Sales Contract for Chemicals . . . . .	502
VIII. Du Pont Stockholdings of \$500,000 and Over . . . . .	506
IX. German Production of Crude and Refined Potash Salts, 1913, 1921, 1924-28 . . . . .	507
X. "Internal Organization of the I.C.I.," by H. J. Mitchell . . . . .	507
XI. U. S. Sulfuric Acid Statistics . . . . .	509



<i>Appendix</i>		<i>Page</i>
XII.	U. S. Production of Contact and Chamber Sulfuric Acid . . . . .	509
XIII.	Distribution of Sulfuric Acid Consumed in U. S. . .	510
XIV.	"The First Contact Sulfuric Acid Plant," by George A. Whiting . . . . .	510
XV.	Sulfuric Acid Plants in U. S., 1929 . . . . .	511
XVI.	U. S. Sulfur Statistics . . . . .	513
XVII.	Sulfur Consumption in U. S. from Various Sources; Sulfur Consumption in Chemical Industry . . .	514
XVIII.	Pyrites in U. S. . . . .	514
XIX.	U. S. Production and Distribution of Ammonia Products . . . . .	515
XX.	U. S. Production and Imports of Nitric Acid . . .	516
XXI.	Production of Phosphoric Acid and Phosphates in U. S. . . . .	516
XXII.	U. S. Phosphate Rock Statistics . . . . .	517
XXIII.	List of Consumers of Phosphate Rock by Uses, 1928	518
XXIV.	U. S. Production of Alkalies . . . . .	520
XXV.	Distribution of Caustic Soda Consumed in U. S. . .	521
XXVI.	Distribution of Soda Ash Consumed in U. S. . . .	521
XXVII.	Alkali Producers in U. S., 1929 . . . . .	521
XXVIII.	U. S. Production of Sodium Sulfates . . . . .	522
XXIX.	Domestic Bauxite Consumed by Various Industries; Producers and Consumers of Bauxite, 1929 . . .	523
XXX.	U. S. Production of Barium Salts . . . . .	523
XXXI.	U. S. Consumption of Crude Barytes in Barium Products; Producers of Barium Products, 1929 . . .	524
XXXII.	U. S. Production of Denatured Alcohol . . . . .	525
XXXIII.	Wood Chemicals Produced in U. S. . . . .	525
XXXIV.	U. S. Production of Coal-Tar and Other Synthetic Organic Compounds, 1923-29 . . . . .	526
XXXV.	U. S. Production of Coal-Tar Crudes . . . . .	534
XXXVI.	"New Processes for Phenol and Aniline," by William J. Hale . . . . .	534
XXXVII.	New Producers of Coal-Tar and Other Synthetic Organic Compounds, 1923-29 . . . . .	536

<i>Appendix</i>	<i>Page</i>
XXXVIII. "Dyes at Marietta, Ohio," by Graham N. Gleysteen	538
XXXIX. Witnesses in U. S. <i>vs.</i> Chemical Foundation, 1923 . . .	539
XL. "Discovery and Development of Ephedrine," by Carl L. Schmidt . . . . .	540
XLI. "Early Development of Ammoniated Superphosphate," by Charles H. MacDowell . . . . .	541
XLII. Code of Trade Practices for the Fertilizer Industry .	542
XLIII. U. S. Production of Insecticidal Arsenic Compounds .	543
XLIV. "Early Work on Furfural Resins," by E. E. Novotny	544
XLV. "Notes on Early Tung Oil Problems," by B. F. Williamson . . . . .	545
XLVI. Production of Important Pigments in U. S. . . . .	546
XLVII. U. S. Rayon Producers, 1929 . . . . .	547
XLVIII. Estimated Heavy Chemical Consumption in Some Chemical Engineering Industries . . . . .	548
XLIX. 1923-29: American Chemical Society; American Institute of Chemical Engineers; American Institute of Chemists; Manufacturing Chemists' Association; Synthetic Organic Chemical Manufacturers' Association . . . . .	549
BOOK TITLES . . . . .	550
ACKNOWLEDGMENTS . . . . .	563
COMPANY AND PERSONAL NAME INDEX . . . . .	567
SUBJECT INDEX . . . . .	607



## ILLUSTRATIONS

<i>Facing page</i>	<i>Facing page</i>
Allen Abrams . . . . .	423
E. M. Allen . . . . .	119
Lester S. Bacharach . . . . .	166
Campbell C. Baird . . . . .	246
D. M. Balsam . . . . .	374
James A. Barr . . . . .	118
James E. Bartlett . . . . .	278
George D. Beal . . . . .	247
James H. Beal . . . . .	279
Edward V. Benjamin . . . . .	134
Edward R. Berry . . . . .	422
Oscar L. Biebinger . . . . .	262
Elmer H. Bobst . . . . .	278
Sevier Bonnie . . . . .	231
Thomas A. Boyd . . . . .	391
Arthur C. Boylston . . . . .	263
Charles J. Brand . . . . .	311
Frederick W. Braun . . . . .	327
Frank G. Breyer . . . . .	358
Edgar C. Britton . . . . .	198
Charles O. Brown . . . . .	55
Sandford Brown . . . . .	214
Charles A. Browne . . . . .	438
Alfred S. Burdick . . . . .	262
C. F. Burroughs . . . . .	310
William M. Burton . . . . .	390
Michael J. Callahan . . . . .	183
G. Lee Camp . . . . .	263
Spencer L. Carter . . . . .	310
Chandler Laboratories . . . . .	439
William H. Charch . . . . .	342
C. L. E. Cheetham . . . . .	55
K. K. Chen . . . . .	279
R. E. Clarke . . . . .	134
Charles C. Concannon . . . . .	6
Richard T. Cotton . . . . .	326
Morris F. Crass . . . . .	7
George O. Curme, Jr. . . . .	182
Harry A. Curtis . . . . .	311
Harvey N. Dauler . . . . .	214
Sidney R. David . . . . .	215
Luis de Florez . . . . .	406
Robert H. de Greeff . . . . .	279
Christian de Guigne . . . . .	38
Harry M. Dent . . . . .	342
Harry L. Derby . . . . .	38
Alfred R. L. Dohme . . . . .	278
Lammot du Pont . . . . .	39
C. P. Dubbs . . . . .	406
Charles H. Dunker . . . . .	215
H. A. B. Dunning . . . . .	246
Graham Edgar . . . . .	391
James B. D. Edge . . . . .	39
George M. Eno . . . . .	7
Joseph Felton . . . . .	295
Colin G. Fink . . . . .	135
Louis B. Fortner . . . . .	215
Rolland H. French . . . . .	166
Howard E. Fritz . . . . .	407
R. S. Fuller, Jr. . . . .	375
Chester A. Fulton . . . . .	118
Charles L. Gabriel . . . . .	183
Henry A. Gardner . . . . .	359
Graham N. Gleysteen . . . . .	215
George A. Goodell . . . . .	231
John B. Gordon . . . . .	359
G. W. Gray . . . . .	406
William T. Haebler . . . . .	294
M. H. Haertel . . . . .	167
Ivan D. Hagar . . . . .	358
Ernest K. Halbach . . . . .	230
William J. Hale . . . . .	198
Carl N. Hand . . . . .	199
Glenn L. Haskell . . . . .	166
Sidney B. Haskell . . . . .	210
R. T. Haslam . . . . .	390
Clarence J. Herrly . . . . .	167
Arthur J. Hill . . . . .	247

	<i>Facing page</i>		<i>Facing page</i>
L. S. Hitchner .....	327	J. C. Patrick .....	407
Waldo C. Hovey .....	167	Walter A. Patrick .....	54
Frank A. Howard .....	390	Charles S. Pearce .....	295
Guy C. Howard .....	423	A. W. Peet .....	295
Samuel Isermann .....	295	Carl B. Peters .....	310
Bernard H. Jacobson .....	135	Alvah H. Pierce .....	230
A. O. Jaeger .....	38	Mark E. Putnam .....	198
Charles F. Kettering .....	391	Edgar M. Queeny .....	39
Morris S. Kharasch .....	247	James A. Rafferty .....	182
J. Warren Kinsman .....	327	Frank H. Reichel .....	343
Sidney D. Kirkpatrick .....	438	Peter C. Reilly .....	199
Henry G. Knight .....	438	Mahlon J. Rentschler .....	134
Charles A. Kraus .....	406	Hiram S. Rivitz .....	375
Eric C. Kunz .....	294	R. C. Roark .....	326
G. B. Landes .....	182	Frederic Rosengarten .....	263
Stewart J. Lloyd .....	326	Frederick W. Russe .....	262
Bevis Longstreth .....	407	Robert P. Russell .....	390
Wilson T. Lundy .....	54	Samuel A. Salvage .....	374
Leland Lyon .....	375	Walter L. Savell .....	135
A. M. McAfee .....	135	Eugene P. Schoch .....	311
Frank L. McCartney .....	278	Max Y. Seaton .....	263
Frank S. MacGregor .....	55	James M. Selden .....	214
James H. McGuire .....	246	Waldo L. Sermon .....	407
George D. McLaughlin .....	423	Philip T. Sharples .....	183
P. George Maerckly .....	54	Richard Sheldrick .....	7
Mallinckrodt Chemical Labs. ..	439	George W. Simon .....	246
B. M. May .....	342	James A. Singmaster .....	358
Otto B. May .....	231	William C. Spruance, Jr. ....	342
Poole Maynard .....	422	John Stauffer .....	38
E. W. Mente .....	134	Sterling Chemistry Laboratory .	439
George W. Merck .....	263	Arthur W. Steudel .....	358
George W. Middleton .....	374	Sidney H. Stilling .....	167
Thomas Midgley, Jr. ....	391	Charles M. A. Stine .....	230
C. Wilbur Miller .....	54	George W. Stocking .....	311
A. J. L. Monitz .....	374	J. Stoddell Stokes .....	343
A. Cressy Morrison .....	6	Philip B. Stull .....	375
Oscar Nelson .....	422	Charles A. Swan .....	294
William B. Newkirk .....	423	Edward A. Taylor .....	119
Lloyd F. Nickell .....	39	William B. Thom .....	119
C. Olin North .....	199	H. Earle Thompson .....	182
Saunders Norvell .....	279	Sydney H. Thompson .....	118
Emil E. Novotny .....	343	Philip S. Tilden .....	7
John W. Orelup .....	231	Ernest T. Trigg .....	327
Victor M. O'Shaughnessy .....	166	Charles N. Turner .....	6
Howard C. Parmelee .....	6	Joseph Turner .....	119
Samuel W. Parr .....	198	A. L. van Ameringen .....	294

# ILLUSTRATIONS

xiii

	<i>Facing page</i>		<i>Facing page</i>
Louis Veillon .....	199	Frank C. Whitmore .....	247
Byrd Walker .....	214	C. K. Williams .....	359
Theodore P. Walker .....	183	B. F. Williamson .....	359
Roger N. Wallach .....	343	John F. Wischhusen .....	326
John J. Watson .....	118	Robert I. Wishnick .....	422
William S. Weeks .....	55	Frederick G. Zinsser .....	230
Gerald L. Wendt .....	438		



## INTRODUCTION

AS FROM A DISTANCE the horizon of a city is dominated by its skyscrapers, so looking backwards at the chemical industry during the 1920's, its mergers stand forth so prominently, they appear to have been the great events of those crowded years. At the time they made the newspaper headlines, attracting the attention of both Wall Street and Washington and furnishing the average citizen with understandable evidence of the vigor and growth of our chemical industry. Within the industry itself, they shifted trade channels, shuffled important personnel, forced many immediate changes that rivetted attention.

It is therefore very convenient to label the years 1923 to 1929, "The Merger Era," and I have done so. But not without some misgivings and the conviction that as a city's tall buildings give no idea of its street plan or its area, its citizens or their activities, so the very conspicuous consolidations do not reveal the most significant chemical developments of that period.

The truly great chemical events of 1923-29 were those associated with the extension of the areas of chemical activity. They took place at the street level, as it were, and the piling up of more centralized control of chemical production—the inevitable result of the natural evolution of chemical manufacturing in this country—had far less influence over the future course of the industry than did the broadening of the chemical base.

We should also remember that while consolidations were a prominent feature of the American business scene at that time, nevertheless the mergers in the chemical field were in a number of ways quite different from those in other industries. Historically, this was the first merger movement among chemical companies. Practically, its mainspring and the direction it took were both quite distinct from the motives and objectives of contemporary combinations.

During the trust-building days of the 1890's chemical manufacturing had remained in the hands of comparatively small, independent enterprisers. Even the corporate form of organization had by no means been universally adopted. With a few notable exceptions, the chemical companies entered the First World War in the proprietor-partnership stage through which other industries had passed a half century before. Accordingly, when the urge to expand by merger finally came, combina-



tion started from a number of closely knit, firmly established, financially strong units.

These independent chemical enterprises had fought hard to win their positions. Moreover, they were compelled to battle endlessly, often bitterly, to keep the prizes of victory. They were captained in the postwar years by new, younger executives. Some were sons and grandsons of the founders, but most of them recruits from the ranks, mainly from the sales staff. Raised in an atmosphere supercharged with the competitive spirit, they scorned the idea of sharing their hard-won position and their cherished independence of action by joining forces with their ancient rivals. Though in an expansionist mood, their entire business experience disinclined them to amalgamation with competitors and nothing in their financial traditions encouraged this idea.

Most of the industry's phenomenal growth in new and bigger plants had been paid for out of earned surplus. Some companies had used their A-1 credit ratings to negotiate short-term loans at their own banks; fewer had privately sold bonds or preferred stock secured by their fixed assets. Save for American Cyanamid, none of the chemical companies had direct connections with Wall Street and so did not have ready access to big blocks of long-term credits through the sale of securities that capitalized good will and discounted an optimistic future.

Thus the industrial and financial training of the industry's leaders supported the technical logic of chemical expansion by means of diversification rather than concentration of productive capacity. To broaden the company's base by acquiring plants, know-how, personnel, and an established position in fresh but allied areas of chemical activity, was the *raison d'être* of the merger movement of the 1920's in the chemical industry. Allied Chemical and Carbon and Carbide furnished the models, and it is noteworthy that not only was this expansive process the very opposite of the concentrating consolidations typical of other industries, but that its effect was to spread, not to eliminate, intercompany competition.

Parenthetically, two other distinctive aspects of these chemical consolidations should not be overlooked. The merger movement in this industry came only after the passage of the anti-trust laws and it was largely consummated before the companies had recourse to public financing. The effect of the Sherman and Clayton Acts was negative, a discouragement to the union of direct competitors; but the financial pattern exerted a very positive influence.

Until 1928-29 most chemical mergers were effected by an exchange of stock based upon an inside, mutually agreeable valuation of tangible assets. In this way the industry escaped, even in the heyday of the Wall Street boom, the easy habit of overcapitalization resulting from writing

up such intangibles as good will, patents, and prospects to cover the underwriters' fees. In a measure these frugal habits made a virtue of necessity. They were forced upon the industry, for many influential financiers then mistrusted chemical enterprises. This conservative financing was rewarded when it became a source of great strength in the stormy days of the Great Depression.

The diversification of production within the companies during the postwar years was but one manifestation of the enormous expansion of all chemical activities. New raw materials—cellulose, the atmosphere, petroleum and natural gas, corn and several fatty oils, rosin and turpentine—all became starting points of big chemical operations. Vast organic chemical enterprises sprang from acetylene and ethylene, and coal tar, formerly the sole passkey to applied organic chemistry, moved out of the relatively restricted field of dyes and medicines and aromatics into the tonnage area of plastics and synthetic resins. Ammonia, methanol, and acetic acid, produced cheaper and in unlimited quantity by new synthetic methods, were bases for new chemical structures. Scores of rare or little-known chemicals came out of the laboratories into the market place, thrusting an unpredictable factor, interproduct competition, into the commercial arena.

Chemical technology was also broadening. The ability to handle high pressures and high temperatures placed new techniques at the command of chemist and engineer. Sturdier and more efficient catalysts made this useful chemical tool more valuable and more widely applicable. Metallurgy provided new alloys of superior resistance for the construction of apparatus of greater capacity and much improved design. Cunning instruments to record and control time and temperature made continuous, automatic operations practical. The uniformity and purity of technical chemicals for rough industrial use reached close to C.P. limits. Mass production entered the realm of chemical manufacture, bringing with it prolific output and lower costs.

A most significant expansion of chemical activity was the reorganization of research to attain large objectives. Prior to World War I, research in the American chemical industry had been confined almost exclusively to plant processes in order to improve products or to lower costs. During the postwar years, technical service to customers focused attention upon the application of chemicals, and the overproduction of many chemicals suggested studies to discover new uses so as to move surplus stocks and relieve the competitive pressure. The natural sequence was to turn this procedure inside out and deliberately to synthesize new chemicals, tailor-made to fill the unsatisfied wants of consumers. These ideas, which seem so simple in retrospect, regenerated applied chemical research in this country. By setting up new, tangible objec-

tives, they awakened a more lively, more understanding interest in research problems among the businessmen of the industry. By reorienting the thinking of research workers, they stimulated fresh efforts that brought fruitful results in every branch of applied chemistry.

All these broadening activities—the diversification of products in the companies, the application of new techniques, the new paths followed by research—had an accumulative effect upon the chemical-consuming industries. New products and new thinking both encouraged the chemicalization of fabricating operations. This extension of chemical activity beyond the old bounds of chemical manufacturing, this rapid spread of the Chemical Revolution, had profound effects upon American chemical manufacturers. While somewhat diverted and greatly obscured during the depression years, their force and meaning were both reaffirmed during the prodigious industrial effort of the Second World War.

It is characteristic of chemical materials and chemical processes that when introduced into any mechanical industry they upset *status quo*. Their electrifying effect upon old industries addicted to rule-o'-thumb methods has often been noted. Indeed their shock is so high-powered that while they vivify the strong, they frequently electrocute the feeble. They are chiefly responsible for that distinctively modern marketing phenomenon, interproduct competition. The steady, constant supply of chemical products and the unfailing uniformity of all their physical and chemical properties had made it easier for many industries to apply the principle of interchangeable parts, upon which the production-line technique depends. Their repeated price reductions throughout the Booming Twenties follow a course that has not been changed by good times or bad; a conspicuous example of the benefits of technological progress passed on promptly to the ultimate consumer; a perfect pattern for "the more abundant life." Though of necessity I deal but briefly with these widening circles of influence beyond the strict confines of the chemical industry, they are implicit in almost every page of the history of these years.

With these explanations of the true significance of the chemical events of 1923-29 and their broader technical and commercial meanings to American economics, it is safe and quite proper, I think, to title this volume "The Merger Era." The designation has two distinct advantages. It identifies the period with the events that cling most persistently in the minds of chemical men. For those outside chemical circles, especially for economists and historians, this title ties the chemical industry into a familiar, easily distinguished epoch. If in the following pages the peculiar methods and aims of the merger movement within the chemical industry have been portrayed with sufficient sharpness and the broadening boundaries of chemical activity have been defined with sufficient

clarity, the convenient label of this volume may through contrast emphasize the trend of postwar events. I trust that it may do so, for it is my hope that in setting forth the chemical record as accurately and as clearly as I am able, my work will make for a better, more general appreciation of the tremendously important function of chemicals in the American economy and inspire others to make specialized studies of the part the Chemical Revolution has played in our history.

WILLIAMS HAYNES

*Stonecrop Farm  
Stonington, Connecticut  
January twenty-eighth, 1947*



## CHEMICAL CHRONOLOGY, 1923-29

In an industry whose activities are so far-flung and complex, often so intimately interrelated, yet sometimes so independent that they appear to operate in a vacuum, it is exceedingly difficult to synchronize and correlate the events into a comprehensive pattern. This Chronology has been designed to help the reader connect the developments in the different branches of the American chemical industry during the years 1923-29—of necessity disjointed in their presentation in the following pages—so as to form a clearer, more connected picture of the chemical activities of the 1920's. It is frankly selective and within a given year the time-sequence of events has not been strictly followed, the first object being to group the facts so as to achieve clarity and emphasis. While based upon the events as recorded in this volume, I have drawn freely upon the Chemical Chronology that Dr. Lawrence W. Bass and I compiled at the time of the Chemical Industries Tercentenary in 1935, the annual chronology of *Chemical Industries*, and the yearly reviews published by that journal, by the *Oil, Paint & Drug Reporter*, and *Chemical & Metallurgical Engineering*. (W. H.)

1923

## GENERAL

Prices continued decline; much price cutting; many manufacturers took over sales from agents. Simplified method of quoting caustic and ash prices adopted. Arsenic market demoralized.

U. S. rayon output passed 25,000,000 lb.

First lacquer-finished automobile (Oakland) and plate glass by continuous process (Ford).

First national Symposium on Colloidal Chemistry; *Monographs* founded.

Chemical Foundation won suit to control enemy-seized patents.

Sulphur (Sullexco) and Naval Stores Export Corporations formed.

*Industrial & Engineering Chemistry, News Edition*, founded.

Alcohol Trades Advisory Committee organized (June 1).

National Safety Council study of benzene health hazard.

C. C. Concannon named chief, Chemical Division, Department of Commerce.

Georgia contracted 100,000,000 lb. calcium arsenate over 5 yrs. from National Gold Arsenic Corp. and American Cotton Growers' Association organized to fight boll weevil.

Arkansas taxed all bauxite mined 25¢/ton.

## INDUSTRIAL-COMMERCIAL

Joseph Turner & Co. succeeded J. L. & D. S. Riker.

Du Pont converted Old Hickory plant to rayon and marketed Duco.

Ohio Salt Co. sole producer of potassium chlorate.

Hoskins Mound, Freeport Sulphur Co., in production (Mar. 31).

Commercial production of ethylene dichloride, Carbide and Carbon Chemicals.

Amyl alcohol from pentane, Sharples Solvents Co. (Sept.).

Citric acid by fermentation in commercial production, Chas. Pfizer & Co.

Barium Reduction Corp. bought Rollin Chemical Co. from receiver.

Bakelite built phenol plant, Painesville, O.

Tennessee Eastman, Kingsport plant built.

First commercial-sized benzene recovery plant on West Coast: Portland Gas & Coke Co.

Commercial Solvents' 2d plant at Peoria in operation (Dec.).

Tryparsamide manufacture licensed to Powers-Weightman-Rosengarten.

*Mergers:* Chile Copper—Anaconda Copper; C. P. DeLore—Mineral Refining & Chemical (bankrupt); Distillers Securities Corp.—Old Time Molasses; Federal Phosphorus—Provident Chemical; Hercules Powder—Yaryan Rosin & Turpentine; St. Joseph Lead—Federal Lead; Sterling Products—Chas. H. Phillips Chemical.

1923

TECHNICAL-SCIENTIFIC

First rubber antioxidant, aldol and naphthylamine, H. A. Winklemann and H. Gray.

Dick test developed for susceptibility to scarlet fever.

Tetraethyl lead tested in laboratory and on road.

Mercury vapor boiler (W. L. Emmet), General Electric.

Du Pont bought American patent rights to Cellophane (French).

Ethylene gas introduced as inhalent anesthetic, Drs. Brown, Luckhardt, and Carter.

Yale dedicated Sterling Chemistry Laboratory.

Soluble specific substance of pneumococcus studied, M. Heidelberger and O. T. Avery.

A. H. Fleming willed \$4,000,000 to California Institute of Technology.

Thiokol discovered, J. C. Patrick.

Aluminum chloride patent, B. H. Jacobson.

Tanners' Council raised fund to build research laboratory.

Amateur motion picture photography developed by Eastman Kodak.

American Institute of Chemists organized.

Mallinckrodt Chemical Laboratories at Harvard.

High-boiling, benzene-free residues from light oil by new process, Semet-Solvay.

CONTEMPORARY EVENTS

France occupied Ruhr Valley.

Earthquake ruined Tokyo and Yokohama.

Ramsay McDonald, Premier of England.

Warren G. Harding died Aug. 2; succeeded by Calvin Coolidge.

Funding of British debt to U. S. negotiated by Stanley Baldwin.



1923 (*Continued*)

## GENERAL

Tung Oil Corp. plantation at Gainesville, Fla.

Vitamin and mineral-enriched bread on market.

Cellulose Division, American Chemical Society, formed.

Color Laboratory set up in Department of Agriculture.

## INDUSTRIAL-COMMERCIAL

*New companies and incorporations:*

Barium Reduction Corp.; Beaver Chemical Co.; Burton T. Bush, Inc.; California Cyanide Co.; Carson Carbon Co. (Ault & Wiborg); du Pont Cellophane Co.; General Motors Chemical Co.; Halowax Corp.; Hydrocarbon Products Co.; Naphthalene Products Co.; National Ultramarine Co.; Soda & Potash Corp.; Virginia Cellulose Co.

## 1924

## GENERAL

Price cutting continued, especially in alkalis; drop in alkaloid prices. Dye sales off 1/3 from 1922. Single producer of potassium chlorate, only two of barium chemicals though Barium Products opened first West Coast plant. Arsenic shortage due to heavy boll weevil infestation. U. S. largest chemical producer, 47% of world total.

"Rayon" adopted as generic term for artificial silk.

Government action against Chemical Foundation to return patents dismissed.

Muscle Shoals bids from American Cyanamid, Union Carbide, Hooker Electrochemical, Henry Ford, and Alabama Power and associates.

Aluminous cement produced, Atlas Luminite Cement Co.

Supreme Court ruled imitator of another's goods must sell his products on own merits.

## INDUSTRIAL-COMMERCIAL

First commercially successful casein plastic in U. S., Karolith Corp.

Acme Rayon Co. in production.

Ethyl Gasoline Corp. formed by General Motors and Standard Oil (N. J.).

Michigan Alkali Co. took over sales from Edward Hill's Son & Co.

Synthetic ammonia manufacture begun by Mathieson Alkali, Niagara Ammonia, du Pont, and Hooker Electrochemical.

New commercial products: trichloroethane and trichloroacetic acid (Dow); ethyl chlorocarbonate (U. S. Industrial Alcohol).

Artificial cryolite successfully in use, Aluminum Co. of America.

Ford Motor Co. Iron Mountain wood-working plant began wood chemicals recovery from scrap.

Manufacture of photographic film, du Pont.

Fused silica quartz glass in production, General Electric.

1923 (*Continued*)

## TECHNICAL-SCIENTIFIC

By-product hydrogen from chlorine cells in production of synthetic ammonia.

*Medals and awards:* R. E. Swain, Chandler medal, atmospheric pollution; Julius Stieglitz, Gibbs medal, organic chemistry; Thomas Midgley, Jr., Nichols medal, internal-combustion engines; M. C. Whitaker, Perkin medal, applied chemistry; H. H. Rusby, Remington medal.

## CONTEMPORARY EVENTS

U. S. recognized Huerta Government in Mexico.

International Opium Conference, Geneva.

## 1924

## TECHNICAL-SCIENTIFIC

First flame-furnace carbon products: Matlock process.

Vitamin D production by irradiation.

Electrolytic production of calcium arsenate, Gulf States Chemical & Refining Co.

Rubber antioxidants, phenyl-naphthylamines (T. Teppema), Goodyear.

Massachusetts Institute of Technology installed industrial X-ray laboratory under G. L. Clark.

Sodium-chlorine cell patented (J. C. Downs), Roessler & Hasslacher.

First produced in U. S.: cyclohexanol (Hexalin), tetrahydronaphthalene (Tetralin), decahydronaphthalene (Dekalin), tetrahydronaphthol (Tetralol).

Manufacture of diagnostic, tetrabromophenolphthalein, Mallinckrodt.

Rubber bonded to metal, Vulcalock, Goodrich.

Iron oxide catalyst for synthetic ammonia patented, A. T. Larson.

Synthetic butanol, Carbide and Carbon Chemicals.

Mercury vapor boiler studied practically.

Koppers process of naphthalene removal from gas.

## CONTEMPORARY EVENTS

Boyce Thompson Institute for Plant Research opened.

First round-the-world air flight.

Anglo-Chilean Nitrate Corp. (Guggenheim) formed in Chile.

Dawes Plan put in operation. London Agreement on German Reparations.

De Valera imprisoned, Belfast, Ireland.

Phenobarbital (Luminal) introduced by Bayer (Germany).

1924 (*Continued*)

## GENERAL

Agricultural Insecticide & Fungicide Manufacturers' Association organized.

*Journal of Chemical Education, Cereal Chemistry, and Chemical Reviews* began publication.

Tariff Commission, *Report on Barium Dioxide*; duty raised to 6¢/lb.

Duty on barbiturates (50%) based on American selling price.

Chlorine Institute organized.

Historic Union Sulphur Co. mine closed after 20 yrs.' production (Dec.).

## INDUSTRIAL-COMMERCIAL

Catalytic oxidation of ammonia applied in manufacture of nitric acid.

Potash on competitive basis marketed, American Trona Co.

National Lead Co. took over Titanium Pigment Co.; built plant in St. Louis.

Vanadium catalyst in production of sulfuric acid.

Merrimac bought Anderson Chemical Co. (lacquers and chemicals).

*New companies and incorporations:* Anglo-Chilean Consolidated Nitrate Corp.; Carbinol Products Co.; General Atlas Co.; Givaudan-Delawanna, Inc.; Grasselli Dyestuff Corp.; A. R. Maas Chemical Co.

## 1925

## GENERAL

Market recovering. U. S. sulfuric acid output passed war peak. Lacquer production up and great rayon activity. Synthetic ammonia and methanol prices reduced sharply.

V. H. McNutt discovered potash near Carlsbad, N. M.

Chromium plating adopted by automobile industry (Oldsmobile).

National Fertilizer Association absorbed Southern Fertilizer Association.

Acetate yarn (Celanese) on market.

Multi-unit tankcar introduced.

Arbitration Act passed (Feb. 12).

## INDUSTRIAL-COMMERCIAL

General Dyestuff bought Grasselli Dyestuff.

Solid carbon dioxide for commercial refrigeration, T. B. Slate patents.

Tryparsamide marketed, Powers-Weightman-Rosengarten.

Abbott Labs. Chicago plant bought by G. D. Searle & Co.

Niacet Chemicals Corp., synthetic acetic acid, acetates, etc., formed jointly by Shawinigan Water & Power, Union Carbide & Carbon, and Roessler & Hasslacher.

Diamond Alkali began production of calcium carbonate.

Cyclohexanol produced commercially.

Commercial production of calcium cyanide, Air Reduction and American Cyanamid.

1924 (*Continued*)

## TECHNICAL-SCIENTIFIC

Silicofluorides as insecticides studied at Tennessee Agricultural Experiment Station.

Chemical Warfare Service field-tested poisons against boll weevil.

National Academy of Sciences dedicated new building, Washington, D. C.

Johns Hopkins new chemical laboratory.

Mullite prepared synthetically, N. L. Bowen and J. W. Grieg.

*Medals and awards:* G. N. Lewis, Gibbs medal; B. D. Saklatwalla, Grasselli medal, vanadium; F. G. Cottrell, Mining & Metallurgical Society of America medal; C. A. Kraus, Nichols medal, nonaqueous solutions; F. M. Becket, Perkin medal, rare metals; G. M. Beringer, Remington medal.

## CONTEMPORARY EVENTS

Teapot Dome oil scandal.

Permalloy cable laid between New York and Azores.

U. S. Immigration Act passed.

## 1925

## TECHNICAL-SCIENTIFIC

Flotation in zinc recovery.

Perfume chemistry course installed at Columbia.

Brewster acetic acid process tested at Keystone Wood Products Co.

Electrolytic reduction of sugars to mannitol (H. J. M. Creighton) resumed by Atlas Powder.

Vanadic pentoxide zeolite catalyst for sulfuric acid, A. O. Jaeger.

Smelting of pyrrhotite concentrates for sulfur begun.

Hexylresorcinol, new antiseptic, Johns Hopkins.

Phenol from monochlorobenzene (W. J. Hale and E. C. Britton), Dow.

Irradiation of sterols studied by H. Steenbock and A. F. Hess.

Bromine from sea water, S. S. Ethyl, du Pont.

## CONTEMPORARY EVENTS

Serious coal miners' strike in U. S.

British Government rejected Geneva protocol for Disarmament Conference (Mar.).

Restricted restoration of gold standard in England (May).

Two 9-power treaties of Washington Armament Conference ratified by Senate (Aug. 5).

Von Hindenberg elected President of Germany.

Italy—American debt funded.

Virginia-Carolina Chemical Co. sold its interest in German potash mines.

1925 (*Continued*)

## GENERAL

Dry Color and Industrial Alcohol Manufacturers' Associations organized.

Insecticide packagings reduced and simplified.

Tariff Commission investigated domestic and foreign methanol costs (July).

Government saccharin suit against Monsanto dismissed.

Pres. Coolidge urged sale of Muscle Shoals to highest bidder.

Zinc Export Association organized.

Duty on potassium chlorate raised to  $2\frac{1}{2}\text{¢/lb.}$

*Chemical Age (N. Y.)* absorbed *Chemical, Color & Oil Record*.

*Chemical & Metallurgical Engineering* reverted to monthly publication.

## INDUSTRIAL-COMMERCIAL

First American production of trichloroethylene and tetrachloroethane, Roessler & Hasslacher.

New aliphatics by Carbide and Carbon in serious commercial production: diglycol diacetate; "Cello-solve"; ethylene dichloride, chlorohydrin, and glycol.

*Mergers:* Calco-Kerin; du Pont-Viscoloid; General Dyestuff Corp., merger of H. A. Metz, Consolidated Color & Chemical, and Central Dyestuff & Chemical; Koppers-American Tar Products; Napon Rayon, merger of H. Doherty Silk and Atlas Powder; Solvay Process-Whitelaw Bros. Chemical; United Carbon, merger of 15 Louisiana producers.

*New companies and incorporations:* American Bemberg Corp.; Belamose Corp.; Burroughs Wellcome & Co.; Dry Ice Corp.; du Pont Rayon Co.; du Pont Viscoloid Co.; Eri-noid Co. of America; Industrial Rayon Corp.; Neville Co.; Ozark Chemical Co.; Pyridium Corp.; Reichhold Chemicals, Inc.; Skenandoa Rayon Corp.; U. S. Potash Co.

## 1926

## GENERAL

Pressure on markets relieved. Increased use of new solvents and ethylene glycol as anti-freeze. Pure benzene below price of 90% grade. Only four refiners of white arsenic operating. Bleaching powder virtually replaced by liquid chlorine. Methanol duty  $18\text{¢/lb.}$

Sharp price cut in ammonia spurred installation in nitration step of chamber process.

National Safety Council report on benzol health hazard.

## INDUSTRIAL-COMMERCIAL

First cuprammonium rayon plant in U. S.: American Bemberg at Johnson City, Tenn.

Du Pont disposed of Chile nitrate mines.

Claude synthetic ammonia plant at Belle, W. Va., Lazote (du Pont).

Semiplant scale flotation of phosphate rock, International Agricultural Corp.

Commercial Solvents Corp. built synthetic ammonia plant at Peoria, Ill. U. S. production of synthetic methanol begun.

1925 (*Continued*)

TECHNICAL-SCIENTIFIC

Trinity College became Duke University.

Electrodeposition of rubber (S. E. Sheppard and L. W. Eberlin), Eastman Kodak.

Continuous fractionation of crude petroleum oils developed industrially.

Students' courses initiated at Chemical Exposition: W. T. Read, director.

Chlorinated rubber processes patented, Carleton Ellis *et al.*

Cellulosic breakfast foods investigated, E. R. Harding.

*Medals and awards:* E. C. Kendall, Chandler medal, thyroxin; Moses Gomberg, Gibbs medal; E. R. Berry, Grasselli medal; E. C. Franklin, Nichols medal, organic chemistry; H. K. Moore, Perkin medal, electrochemistry, pulp, hydrogenation; H. M. Whelpley, Remington medal.

CONTEMPORARY EVENTS

Sun-Yatsen died in China.

I.G. Farbenindustrie formed in Germany (Nov. 28).

Security Pact initiated at Locarno (Nov.).

German Bromine Convention broken up (Nov.).

Discovery of Boliden gold mine rich in arsenic, in Sweden.

1926

TECHNICAL-SCIENTIFIC

Commercial development of gas dehydration, Koppers Co.

Direct recovery system for coal tar, Barrett Co.

Aniline from monochlorobenzene and ammonia (W. J. Hale and E. C. Britton), Dow.

Ethylene "ripening" of citrus fruits and fast freezing of foods on commercial scale.

Amyl compounds synthesized from pentane, Sharples Solvents.

Atomic hydrogen welding developed, Irving Langmuir, *et al.*

CONTEMPORARY EVENTS

German and French potash syndicates divided world markets.

German producers of barium carbonate formed cartel.

First International Conference on Bituminous Coal, Pittsburgh.

English general strike (May); serious coal stoppage.

Sesquicentennial Exposition, Philadelphia (May 31).

1926 (*Continued*)

## GENERAL

- Sale of tetraethyl lead-treated gasoline approved by Government.
- Copper Exporters, Inc., formed under Webb-Pomerene Act.
- Lacquer production first 6 months showed 62% increase.
- Industrial Alcohol Manufacturers' Association formed.
- U. S. led world production of iron, copper, petroleum, coal, phosphate, sulfur, fluorspar, gypsum, magnesite, lead, zinc, talc and soapstone, barytes, tungsten concentrates, aluminum metal, and manganese.
- U. S. Bureau of Engraving & Printing adopted chromium plates for engraving currency.
- Congress voted \$185,000 for Fixed Nitrogen Lab. and \$100,000 for potash prospecting.
- Rayon makers switching from linters to wood cellulose.
- Rasorite (hydrated sodium borate) deposits found in California.
- U.S.P. X. became official; 11 natural alkaloids deleted, 17 synthetic chemicals admitted.
- Federal court fined 38 fertilizer companies for unfair trade practices (Dec.).
- Williamstown Institute of Politics conference on chemicals in world affairs.
- First "Chemical Day" at Department of Commerce, Secy. Hoover, speaker.
- Safety glass generally introduced in stock models of motor cars.
- Supreme Court upheld Government sale of patents to Chemical Foundation.
- American Paint & Varnish Manufacturers' Association, consolidation of National Varnish Manufacturers' Association and Paint Manufacturers' Association of U. S.

## INDUSTRIAL-COMMERCIAL

- General Chemical built new fine chemicals and reagents plant at Delaware works.
- New aldehydes offered commercially, Niacet Chemicals Corp.
- Mergers:* American Home Products Corp., merger of Wyeth Chemical, Larned, Deshell, Edward Wesley; American Solvents & Chemical Corp., merger of Everett Distilling, Jefferson Distilling & Denaturing, Crescent Industrial Alcohol, Western Industries, and Witbeck Chemical; Cook & Swan—Frank L. Young Co.; Davison Chemical—Eastern Cotton Oil and Alliance, Camp, Meadows, and Miller Fertilizer; Heyden—Norvell; McKesson & Robbins—Girard; Mathieson Alkali—Fields Point Mfg.; Palmolive—Peet; Pennsylvania Salt—Eagle Lye; G. S. Robins—Whitelaw Bros. (non-alkali agencies); Standard Varnish Works—Toch Bros.; Stauffer—Niagara Smelting; Union Carbide and Carbon—U. S. Vanadium; U. S. Industrial Alcohol—N. J. Alcohol & Chemical and Crystal Chemical; Virginia Cellulose—Hercules Powder; Zinsser—Ultron Chemical.
- New companies and incorporations:* Alox Chemical Co.; Alton Barium Products Co.; American Anode, Inc.; American Potash Co.; American Potash & Chemical Corp.; Buckeye Soda Co.; Buffalo Electro-Chemical Co.; Chromium Corp. of America; du Pont National Ammonia Co.; Duval Texas Sulphur Co.; Eastern Alcohol Corp.; General Plastics, Inc.; Heyden Chemical Corp.; Marietta Dyestuffs Co.; Norwich Chemical Co.; Pyroxylin Products; Resinous Products & Chemical Co.; Sharples Solvents Corp.; Tar Acid Refining Co.; Westvaco Chlorine Products Corp.

1926 (*Continued*)

## TECHNICAL-SCIENTIFIC

Chemical activation by alpha particles studied by S. C. Lind.

R. E. Hall process for conditioning boiler water placed on commercial basis.

First Organic Chemistry Symposium held, Rochester, N. Y.

Illinium discovered, B. S. Hopkins *et al.*

First electrolytic production of hydrogen peroxide in U. S.

Ultraviolet photomicroscopy developed (F. J. Lucas), Bell Telephone Labs.

Cuprous oxide as antifouling agent for ship-bottom paints, Rohm & Haas.

Oberphos process for superphosphate, Ober & Sons.

Guggenheim process of nitrate recovery in commercial operation in Chile (Nov.).

*International Critical Tables* began publication by National Research Council.

American Chemical Society Golden Jubilee, Philadelphia, and International Union of Pure & Applied Chemistry, Washington, D. C.

Nitrocellulose molding powder and nitrocellulose sausage casing introduced in U. S.

Diphenyloxide from monochlorobenzene.

Ephedrine (K. K. Chen) manufactured by Eli Lilly.

*Medals and awards:* William Blum, American Institute of Chemists medal, electrochemistry; S. W. Parr, Chandler medal, coal; J. C. Irvine, Gibbs medal, carbohydrates; C. R. Downs, Grasselli medal, catalytic oxidation; D. C. Jackling, Mining & Metallurgical Society of America medal; S. C. Lind, Nichols medal; R. B. Moore, Perkin medal, radium, mesothorium, helium; E. F. Smith, Priestley medal; H. A. B. Dunning, Remington medal.

## CONTEMPORARY EVENTS

Silica gel catalyst, W. A. Patrick (1919), had first industrial trial in Belgium.

Weizmann's fermentation patents as against Fernbach's upheld in English court, in *Commercial Solvents vs. Synthetic Products*.

Japanese outrages against foreigners; Hirohito became Mikado.

Germany entered League of Nations (Sept. 8).

Safeguarding of Industries Act, England.

I.G. bought rights to U. S. tetraethyl lead.

Imperial Chemical Industries formed by merger of Brunner-Mond, British Dyestuffs, Nobel Industries, and United Alkali (Oct.).

Chilean nitrate plants closing.



1927

## GENERAL

Demand for all chemicals brisk. Sal ammoniac shortage because of radio boom. Interproduct competition among solvents and between lacquers and varnish.

American independence of foreign bismuth: improved technology.

Sodium nitrite approved in meat curing.

Right of importer to inspect manufacturers' cost figures upheld by Supreme Court.

Food, Drug & Insecticide Administration established in Department of Agriculture; Bureau of Chemistry & Soils reorganized.

Anti-trust suits against potash and quinine cartels.

Dr. James M. Doran, head of Prohibition Bureau.

Campaign against methanol as poisonous denaturant.

Association of Consulting Chemists & Chemical Engineers founded.

Zinc Export Association, Inc., and Copper Institute formed.

Fertilizer industry drew up code of ethics.

National Lead Co. bought Norwegian and French titanium pigments companies.

American rights to Bergius coal hydrogenation process was acquired by Standard Oil (N. J.).

Supreme Court ruled Germans whose American properties were seized during war could get redress only through their own Government (Apr.).

## INDUSTRIAL-COMMERCIAL

American Nitrogen Products Co. dissolved after plant burned down.

Hopewell synthetic ammonia plant built, Allied Chemical & Dye.

Synthetic methanol on large scale from Commercial Solvents and du Pont.

International Agricultural Corp. fertilizer phosphate plant at Wales, Tenn.

Pacific Coast Borax Co. abandoned Death Valley for California rasorite deposits.

Caustic soda from trona at Owens Lake, Calif., Clark Chemical Co.

Solvay electrolytic chlorine plant, Syracuse, N. Y.

First synthetic ammonia unit, West Coast, Great Western Electro-Chemical Co.

Publicker, Inc., entered chemical solvents field.

Titanium oxide by Blumenfeld process, Commercial Pigments Corp.

All higher aliphatic alcohols from unsaturated hydrocarbon gases and many corresponding acetates in commercial production.

*Mergers:* American Home Products merged 4 companies; Calco—Williamsburg Chemical; California Chemical—Industrial Chemical and Whitney Chemical; Chemical & Dye Corp., merger of Chemical Co. of America, New England Aniline, and Tower Mfg.; Copper Pyrites—Ducktown Chemical & Iron; Davison—Lewes Fertilizer and Pick Fertilizer Service; A. Klipstein—Dunker & Perkins; Merck—Powers-Weightman-Rosengarten; Oldbury Electro-Chemical—Phosphorus Compounds; Semet-Solvay Engineering—Steere Engineering; Southern Dyestuffs—Elko Chemical; Westvaco Chlorine Products—Warner.

1927

## TECHNICAL-SCIENTIFIC

Fertilizer from sewage and trade wastes at Milwaukee.

New York University Nichols Chemistry Building dedicated.

Cooperative research for new uses, Interstate and Texas Cottonseed Crushers' Associations.

First Institute of Chemistry at Penn State College.

Selden vanadium catalyst for sulfuric acid patented, A. O. Jaeger.

Davison contact sulfuric acid plant using silica gel catalyst.

Brewster patent for synthetic acetic acid invalid; priority of invention.

Light aluminum alloys introduced.

Du Pont acquired American rights to Casale ammonia process, Acele acetate rayon, Liljenroth phosphoric acid process.

Electrodeposited rubber introduced, American Anode, Inc.

Glyptal resins developed, General Electric.

Acetic acid from fruit pits, Western Industries.

Alpha Fibre cellulose produced, Brown Co.

Vinyl chloride photographic film patented.

Magnesium hydroxide from sea water, Marine Chemicals.

Bleaching of kraft paper patented.

New Jersey Zinc's lithopone patents licensed to 7 manufacturers.

Chromium plating patents consolidated in General Chromium Corp.

## CONTEMPORARY EVENTS

U. S. Marines landed in Nicaragua.

Civil war in China.

International Economic Conference, Geneva, attended by 47 nations (May). International Chamber of Commerce, Stockholm (June-July).

Société des Phosphates Tunisiens bought rights to Swann electrothermal phosphoric acid process.

Morocco began exporting phosphate rock to U. S.

Lindbergh flew Atlantic (May 10).

Naval Armaments Conference, Geneva: England, U. S., and Japan (June-Aug.).

In England, Trades Dispute Act passed making general strike illegal.

King Ferdinand of Rumania succeeded by Michael.

Sacco and Vanzetti case.

British Copper Sulphate Association organized.

1927 (*Continued*)

## GENERAL

Ethylene glycol production 12,000,000 lb., a 100% increase over 1920.

Dow sole domestic producer of magnesium.

Duties lowered on phenol and cresylic acid; raised on magnesite and sodium.

*Drug & Chemical Markets* (weekly) became *Chemical Markets* and *Drug Markets* (monthlies).

*Standards Yearbook* published.

## INDUSTRIAL-COMMERCIAL

*New companies and incorporations:* American Catalin Corp.; American Glanzstoff Corp.; American Mercury Co.; Bayway Industrial Chemical Co.; Belle Chemical Co.; Celanese Corp. of America; Commercial Pigments Corp.; Consolidated Chemical Industries; Elko Chemical Co.; Furness Corp. (rayon); Georgia-Louisiana Chemical Co.; International Mercury Corp.; Kay Laboratories, Inc.; Keystone Wood Chemical & Lumber Corp.; Lacquer Chemicals, Inc.; National Chromium Corp.; New England Chemical Co.; Sand Springs Chemical Co.; Singmaster & Breyer; Smith-Rowland Co.; Solid Carbonic Co.; Solvay-American Investment Corp.; Synthetic Nitrogen Products Corp.; Triplex Safety Glass Co.

## 1928

## GENERAL

Chemical demand stronger, broader. Drastic price reductions opened new uses for borax and aluminum chloride. Greatest consumption of liquid chlorine in chemicals. Influenza epidemic (Nov.) created abnormal need for many medicinals. Mercury at all-time high of \$132.50 per flask. A year of good business.

During past 10 yrs., 7,259 industrial mergers, 355 chemical.

First nitric acid tankcar.

Constitutionality of flexible provisions of 1922 Tariff Act upheld by Supreme Court: Tariff Commission *vs.* J. W. Hampton, Jr., & Co.

*Rubber Chemistry and Technology* founded.

Tariff Commission, *Report on Magnesite*.

## INDUSTRIAL-COMMERCIAL

Penn Salt and Hooker Electrochemical built alkali plants on West Coast.

Old Hickory Chemical Co. (carbon bisulfide) established by Stauffer and du Pont.

Synthetic acetone produced commercially, Niacet Chemicals.

Blast-furnace production of phosphoric acid, Victor Chemical.

True calcium hypochlorite marketed by Mathieson Alkali.

Merthiolate, mercury antiseptic, offered by Eli Lilly.

Fertilizer ammonium phosphate, Montana plant of Anaconda Copper.

American Cyanamid began manufacturing phosphate salts.

Atlas Powder in coated fabrics field (Duratex).

Ethyl oxybutyrate and lactate by new process, American Cyanamid.

1927 (*Continued*)

TECHNICAL-SCIENTIFIC

Safety glass and nitriding of steels commercially important.

Masonite insulating board.

Bakelite patents expired.

*Annual Survey of American Chemistry* published by National Research Council.

*Medals and awards:* L. B. Mendel, American Institute of Chemists medal, biological chemistry; Moses Gomberg, Chandler medal; J. J. Abel, Gibbs medal, glandular extracts; Roger Adams, Nichols medal, chaulmoogra oil acids; J. E. Teeple, Perkin medal, potash; O. G. Thurlow, Potts medal.

CONTEMPORARY EVENTS

New York-to-London telephone communication established.

German and French potash syndicates opened N. Y. office.

Chile nitrate producers returned to free selling.

1928

TECHNICAL-SCIENTIFIC

Electrodeposition of metals on aluminum developed (H. K. Work), Mellon Institute.

Diphenyl, Federal Phosphorus Co.

Carboloy, General Electric Co.

Photoelectric cell applied to technical problems.

Alpha cellulose from cornstalks, Dorrner process, Cornstalk Products Co.

Ethylene oxide as insecticide, R. T. Cotton and R. C. Roark.

Ammoniation of superphosphate introduced commercially.

Chemical Foundation (F. P. Garvan) sponsored John J. Abel Fund for Research on Common Cold.

CONTEMPORARY EVENTS

Mercurio Europeo, mercury cartel, reorganized by Spanish and Italian producers.

Chiang Kai-shek, President of China.

Synchro - mesh transmission introduced by Cadillac.

European Zinc Cartel formed (May).

Second International Nitrogen Conference on S. S. Lützow in Adriatic (Apr.-May).

1928 (*Continued*)

## GENERAL

Antidumping orders against importation of Moroccan phosphate rock and Italian calcium citrate.

Industrial Alcohol Manufacturers' Association reorganized as Industrial Alcohol Institute.

Sale of "Ethyl" gas in N. Y. City approved.

Naval Stores Export Corp. disbanded.

Duty on barium carbonate raised to 1½¢/lb. (Mar.); 25% ad valorem duty (American selling price) on sodium silicofluoride (Aug.).

Duval Texas Sulphur Co. pumped Palangana Dome.

Duplate (safety glass) on the market.

First commercial paper from cornstalk pulp, Danville, Ill.

Roanoke plant of Viscose Co. largest in world: 20,000,000 lb. rayon/yr.

First American Chemical Society Economic Symposium, subject nitrogen.

*Journal of Research* and *National Directory of Commodity Specifications* (Bureau of Standards) began publication.

S. D. Kirkpatrick succeeded H. C. Parmelee, editor of *Chemical & Metallurgical Engineering*.

American Pharmaceutical Association opened Washington, D. C., office.

## INDUSTRIAL-COMMERCIAL

First shipment synthetic sodium nitrate from Hopewell, Va., by Atmospheric Nitrogen Co. (Allied Chemical).

Wood Distillers Corp. organized to refine and sell methanol of affiliates.

Ethanolamines available from Carbide and Carbon Chemicals.

*Mergers:* Abbott Labs.—John T. Milliken; American Commercial Alcohol—American Distilling, David Berg Industrial Alcohol, and S. M. Mayer Alcohol; J. T. Baker—Dissosway and Taylor Chemical; Celanese—Celluloid; Colgate-Palmolive-Peet; Davison Chemical—Read Phosphate, Southern Phosphate, Welch Chemical, and Porter Fertilizer; du Pont—Grasselli and North Hudson Chemical; International Combustion Engineering—F. J. Lewis Mfg.; Norwich Pharmacal—Amolin; Paper Makers' Chemical Corp. merged 8 firms; Pennsylvania Salt—Central Commercial (silicates) and North American Chemical (ammonium persulfate); Union Carbide—Acheson Graphite, Michigan Ox-Hydric, American Carbolite, and Memphis Oxygen.

*New companies and incorporations:* American Enka Corp.; Bay Chemical Co.; Bayer-Semesan Co.; Blockson Chemical Co.; Bush Aromatics, Inc.; Chilhowee Co.; du Pont Ammonia Corp.; C. P. Hall Co. of Calif.; Halowax Corp.; J. H. Heald; Hurley-Johnson Corp.; International Combustion Tar & Chemical Corp.; Naval Stores Marketing Corp.; Rosland Corp.; Ruggles & Rademaker; Sodium Products Corp.; Standard Potash Co.; Tacoma Electrochemical Co.

1928 (*Continued*)

## TECHNICAL-SCIENTIFIC

Commercial-scale flotation of Florida phosphate rock, International Agricultural.

Ammonia oxidation (du Pont and General Chemical) and ammonia nitration (du Pont, Davison, and Armour) in commercial operation.

Joint meeting of American Institute of Chemical Engineers and Institute of Chemical Engineers of Great Britain.

Vanadium catalysts in sulfuric acid production, Selden and General Chemical.

Vapor-phase cracking of petroleum redeveloped.

Pure algin produced commercially, Thornley & Co.

Irradiated foods introduced.

New Chandler Labs. opened at Columbia.

*Medals and awards:* J. A. Wilson, Chandler medal, leather chemistry; W. D. Harkins, Gibbs medal, isotopes; H. J. Rose, Grasselli medal, by-product coking; H. H. Rusby, Hanbury medal, drugs; W. D. Coolidge, Hughes medal of Royal Society, X-rays; H. S. Taylor, Nichols medal, catalysis; T. B. Osborne, Osborne medal, cereal proteins; Irving Langmuir, Perkin medal; E. C. Sullivan, Potts medal; C. H. La Wall, Remington medal.

## CONTEMPORARY EVENTS

Merchant Marine Act (mail subsidy) passed.

Chilean Nitrate Producers' Association resumed fixing prices (July).

First sound motion picture demonstrated, N. Y. (July 6).

Radio television.

Etablissements Kuhlmann merger in France.

Nitrogen Engineering Corp. built Casale plant near Paris for Etablissements Kuhlmann.

Kellogg Pact outlawing war signed in Paris by 15 nations (Aug. 27).

Graesser-Monsanto Chemical Works, Ltd., acquired 3 English coal-tar products properties.

Largest anhydrous alcohol plant in world building in Berlin, for motor fuel.

1929

## GENERAL

Chemical demand slackened, forecasting collapse, and competition from abroad involved many cases of "dumping." Sulfuric acid reached new high of 8,491,114 short tons, 50° Bé.,  $\frac{2}{3}$  made from brimstone. Soda ash production 100% and caustic soda 50% above World War I records. "Chemical & Allied Products" valued by *Census* at \$3,-759,404,640, compared with 2 $\frac{1}{4}$  billions in 1921.

Automobile output: 5,621,715 new cars.

Production of sulfur at Boling Dome, Texas Gulf Sulphur Co.

Vanadium catalysts patent suits, Monsanto *vs.* Jaeger *et al.*, and General Chemical *vs.* Selden.

U. S. anti-trust suit against foreign potash monopoly settled by consent decree (Feb.).

Maj. Gen. H. L. Gilchrist, chief, Chemical Warfare Service.

Helium plant, Amarillo, Tex.

Prohibition Bureau permitted commercial production of alcohol from ethylene.

Over 100 firms making refrigeration equipment.

Wood Chemical Institute, Inc., succeeded National Wood Chemical Association (Mar.).

Vanadium chemical products, only 1-2 yrs. old, valued at \$75,000-\$100,000 yr.

Wood rosin industry adopted code of ethics.

Solvents Institute, Rayon & Synthetic Yarn Association.

Institute of Paper Chemistry, Lacquer Institute founded.

## INDUSTRIAL-COMMERCIAL

U. S. Potash Co. drilled commercially for potash, Carlsbad, N. M.

Diamond Alkali chlorine electrolytic plant, Painesville, O.

Ethyl abietate marketed, Hercules Powder.

Hoffman-La Roche opened Nutley, N. J., plant.

Shell Chemical Co. organized to make carbon black and synthetic ammonia (Mont Cenis process).

*Mergers:* American Commercial Alcohol—Orleans Distilling and Kessler Chemical; American Commercial Alcohol of Calif.—International Solvents; American Cyanamid—American Powder, Calco, Chemical Engineering, Kalbfleisch, and Selden; American Home Products merged 5 firms; American I.G.—Grasselli Dyestuff; American Solvents & Chemical—Cragin Products; Ansbacher-Siegle Corp., merger of Ansbacher Corp., G. Siegle Corp., and Contex Color; Calco—Crown Chemical, Textile Chemical, King Chemical (sulfur dioxide), and May Chemical (lake dyestuffs); Commercial Solvents—Commercial Pigments; Davison Chemical—Berkshire Chemical, Central Chemical, Lancaster Bond Fertilizer, Fremont Cotton Oil, Oxford Packing, and Washington, Alexander & Cook; Drug, Inc.—Three-In-One Oil and Bristol-Myers; du Pont—Krebs Pigment, du Pont Rayon, and du Pont Cellophane; du Pont Cellophane—Capes-Viscose; Federal Phosphorus—Iliff-Bruff Chemical; General Industrial Alcohol Corp., merger of General Industrial Alcohol Co., National Industrial Alcohol, Greendale, and Michigan Chemical, and later Molasses Distributors; Hercules Powder—Virginia Cellulose; Koppers—White Tar; Kentucky Color & Chemical—National Ultra-

1929

TECHNICAL-SCIENTIFIC

Acetone from natural gas propylene, Carbide and Carbon Chemicals.

Commercial production of magnesium sulfate from magnesium hydroxide, Dow.

Alkyd resins, Glyptals, introduced commercially by General Electric.

Lawrence invented cyclotron for atomic research.

46 derivatives of diphenyl prepared.

New aliphatics offered by Carbide and Carbon: isopropanol, methyl Cellosolve, dioxane, ethylene oxide, dichloroethyl ether, and vinyl chloride.

Sanforizing process of shrinking cloth, S. L. Cluett.

Petroleum hydrogenation on semi-commercial scale, Standard Oil (N. J.).

Polaroid glass, E. H. Land.

Fire-resistant films (cellulose triacetate) and commercialization of colored moving pictures, Kodak.

Koppers phenol recovery from crude ammonia liquor perfected and installed at Hamilton Coke & Iron Co.

Battelle Memorial Institute opened, Columbus, O.

George H. Jones Lab. dedicated, University of Chicago.

Xylose from cottonseed hull bran, semicommercial scale, Bureau of Standards.

Fermentation gluconic acid commercial process (B. M. May and H. T. Herrick), Bureau of Standards.

Aliphatic thiocyanates (Lethane) marketed as insecticides, Rohm & Haas.

CONTEMPORARY EVENTS

European Zinc Cartel collapsed (Jan.).

Kellogg-Briand Anti-War Pact in effect.

Belgian Congo, world headquarters for copper.

Papal State recreated.

New nitrate fields bought by Guggenheim from Chilean Government and Lautaro Nitrate Corp. formed to work Guggenheim process.

International Nitrogen Cartel formed: Germany, Great Britain, Chile (July).

First large-scale fertilizer ammonium phosphate output, Société des Phosphates Tunisiens (American process).

Meeting of European representatives of Bureau of Foreign & Domestic Commerce with Concannon, in Paris.

Union Carbide and Carbon bought 4 hydroelectric plants in Norway.

Chile borax production abandoned because of California competition.

Dutch interests acquired Consolidated Gold Fields holdings in American Potash & Chemical Corp.

Foreign producers resigned from Copper Exporters, Inc.

First all-metal dirigible completed.



1929 (*Continued*)

GENERAL

Dumping of salt cake by Germany protested by American producers.

White arsenic from domestic ores at standstill.

Textile mills spinning and weaving over 136,000,000 lb. synthetic fibers, more from wood cellulose than cotton linters.

Increasing imports of German butyl acetate seriously curtailed American production.

All potassium chlorate imported.

4,000 acres of tung trees planted in Florida.

*Metals & Alloys and Industrial & Engineering Chemistry, Analytical Edition*, founded.

*Pharmaceutical Recipe Book* published by American Pharmaceutical Association.

Carbon Black Export Association formed.

15 billion dollar decline in stock values (Nov.-Dec.).

Pres. Hoover named Economic Council of industrial leaders.

INDUSTRIAL-COMMERCIAL

marine; Monsanto—Commonwealth Chemical Div. of Mathieson Alkali, Merrimac, and Rubber Service Labs.; National Acetate Silk, merger of American Chatillon and Tubize Artificial Silk; Naugatuck Chemical—Rubber Regenerating and Dispersions Process; Newport—Rhodia Chemical; Pennsylvania Sugar—Franco-American Chemical; Reichhold Chemicals—Synthe-Copal; Rossville Commercial Alcohol, merger of Rossville, Orange Grove Refining, Federal Products, Seaboard Chemical, and Industrial Chemical Mfg.; Sharp & Dohme—H. K. Mulford; Smith, Kline & French—V. H. Smith; Standard Brands, Inc., merger of Royal Baking Powder and Fleischmann; Union Carbide & Carbon—Standard Chemical and Vanadium Alloys; United Feldspar, merger of 4 firms; U. S. Industrial Alcohol—Kentucky Alcohol; van Ameringen—Morana; Van Dyk—Norda Essential Oil & Chemical; Westvaco Chlorine Products—Barium Products, Curtin-Howe, Monarch Chemical, and Peroxide Mfg.

*New companies and incorporations:* Agricultural Potassium Phosphate Co. of Calif., Ltd.; American Commercial Alcohol Co. of Calif.; American I.G. Chemical Corp.; Carbon Dioxide & Chemical Co.; Catalytic Process Corp.; Chemical Construction Corp.; Duplate Corp.; New Bedford Rayon Co.; Newberry Lumber & Chemical Co.; Schering Corp.; Solid Carbon Dioxide Corp.; Sylvania Industrial Corp.; Union Solvents Corp.; United Chemicals, Inc.; van Ameringen-Haebler, Inc.; Woonsocket Rayon Co.

1929 (*Continued*)

## TECHNICAL-SCIENTIFIC

First production of *o*-chloroaniline in U. S., Monsanto.

Ethyl vanillin, Pfizer.

Rapid-drying varnishes and enamels introduced.

*Medals and awards:* E. G. Acheson, Acheson medal; Oliver Kamm, American Association for the Advancement of Science prize, pituitary hormones; F. P. Garvan, American Institute of Chemists and Priestley medals; Irving Langmuir, Chandler medal; C. S. Hudson, Gibbs medal, carbohydrates; Bradley Stoughton, Grasselli medal, light alloys; W. L. Evans, Nichols medal, carbohydrates; E. C. Sullivan, Perkin medal, glass; W. L. Scoville, Remington medal; C. P. Dubbs, John Scott medal, petroleum cracking.

## CONTEMPORARY EVENTS

World flight of *Graf Zeppelin* made on Pyrofax (propane) fuel.

Stock market break (Sept. 5).

Dr. A. Fleming observed penicillin University of London.



*PART ONE*

THE BOOMING TWENTIES



## *Chapter 1*

### THE RETURN TO NORMALCY

BOOMING AUTOMOBILE, MOTION PICTURE, AND RADIO INDUSTRIES CREATE NEW CHEMICAL DEMANDS—COOLIDGE ADMINISTRATION COOPERATES WITH INDUSTRY; REDUCES PUBLIC DEBT AND TAXES—SECRETARY OF COMMERCE HOOVER URGES COLLECTION OF STATISTICAL DATA AND APPOINTS CHEMICAL ADVISORY COMMITTEE—ANTIDUMPING AND FLEXIBLE PROVISIONS OF 1922 TARIFF UPHELD IN COURT, BUT AMERICAN VALUATION FAILS.

PRESIDENT HARDING signed the Fordney-McCumber Tariff Law on September 21, 1922, and his slanting signature was hardly dry before business in all lines began to revive from the sharp slump that had begun in the autumn of 1919. The immediate effects of this frankly protective tariff upon general business were chiefly psychological, but they proved to be quite intoxicating.

The dormant demand for consumer goods—so dormant that it had been bitterly described by industrialists as a “buyers’ strike”—did not immediately leap to life. However it stirred and, reassured by the returning feeling of confidence, buoyed up by the holiday spirit, it struck a new pace in the Christmas trade. This pace speeded up throughout 1923, swifter and swifter, until it became the reckless orgy of spending that ended only in the resounding crash of 1929.

The encouragement given American producers of chemicals by the new tariff was direct and double. It assured them that the war-born coal-tar branches of the industry would be safe from destructive foreign competition for at least the next five years. The coal-tar chemicals having acquired at this time almost a symbolic significance, this assurance was widely interpreted as official recognition of the key importance of chemicals in the national economy; a green light, as it were, opening the highway to chemical progress. By the same token, the new tariff extinguished any hope industrial consumers of synthetic organic chemicals might have cherished of benefiting from a bitter price war waged by European chemical manufacturers to rewin the American market. Accordingly, the demand for coal-tar dyes, medicinals, and aromatics, which had been hesitant, awaiting the outcome of the tariff controversy, picked up immediately and brought with it increased calls for many other chemicals.

Throughout the Booming Twenties, the consumer demand for every-

thing from a safety pin to a house-and-lot constantly outran supply, furnishing the incentive for a tremendous industrial expansion and engendering the optimistic belief that an entirely new economic era, based upon an infinitely growing prosperity, had been created. The changes wrought in American life during this amazing decade far exceeded those of the fifty years previous, and the chemical industry was the first and most direct beneficiary of this burst of material progress.

The millionth automobile had appeared in 1916, and by 1920 the "horseless carriage" had ceased to be a highway curiosity that astonished the natives and frightened the horses out of their wits. But it was still a luxury vehicle. Between 1922 and 1929, however, the number of passenger cars and trucks in service throughout the country grew from eleven and a half million to over twenty-five.<sup>1</sup> During the latter year alone, 5,621,715 new motor cars were made and sold. These figures are but the outward and visible sign of far-flung developments that closely affected chemicals. The basis of mass production methods in all modern mechanical industries, the pregnant idea of interchangeable parts, first discovered by the Connecticut clockmaker, Eli Terry,\* was refined and widely extended in the automobile plants of the twenties. The bottleneck at the end of the new assembly lines was broken by the development of quick-drying synthetic lacquers which cut the time of finishing the car from days to hours. As in the case of textiles when chemical bleaching broke the jam and made power-spinning and weaving practical, the chemist again came to the rescue of the mechanic.

A most grievous fault of the early motor cars, ignition trouble, was cured by synthetic plastics that replaced porcelain and rubber distributor heads. The growing number of automobiles on the road increased enormously the demand for gasoline, lubricants, and rubber,† initiating revolutionary chemical developments that gave us "more miles per gallon" and lengthened the life of tires. In the meantime, the nation's twisting, rutted roads, veritable quagmires in winter and early spring, were being rapidly smoothed and straightened and hard-surfaced. More

\* The illustrious inventor of the cotton gin, Eli Whitney of New Haven, is commonly credited with this invention, too, but the pistol maker, Simeon North of Berlin, Conn., has as good a claim. Eli Terry of Plymouth, Conn., was making 20 clocks at a time with three apprentices working with water-power driven tools before 1800. Whitney's rifles made of interchangeable parts were not delivered to the U. S. Govt. till 1806. Terry for a short time had as his partner Seth Thomas, who went out for himself in 1810. These four were between them responsible for the development of the key to assembly-line production in our mechanical industries.

† Between 1919 and 1929, according to Bur. Mines figures, production of natural gasoline increased from 2,957,000 gal. to 48,457,000; cracked gasoline from 14,490,000 gal. to 143,727,000, or a rise from 4.28% to 14.55% of all the crude oil run. In 1919 our imports of crude rubber were 214,000 tons; in 1928, 135,000 tons, two-thirds of world consumption. Two-thirds of this rubber went into the manufacture of some 75,000,000 automobile tires. (See Macedo Soares, *Rubber*, pp. 26-30.)

and more the automobile became a practical means of transportation for pleasure and for business, and year after year fewer cars were laid up during the winter months. Cold-weather driving encouraged blended fuels and made necessary the use of anti-freeze solutions in radiators. Benzene and alcohol were influenced importantly; tetraethyl lead and ethylene glycol appeared to meet these new needs.

Paralleling this automotive revolution, other fast-growing industries created new chemical demands. During this amazing decade, the nickel-odeon blossomed into the moving picture palace; John Bunny, Francis X. Bushman, King Baggot were succeeded by Charlie Chaplin, Mary Pickford, Fatty Arbuckle; flickering films that snapped were eliminated and the photographic technique startlingly improved. In 1927 the first sound picture was distributed; within two years practically every one of the country's 20,000 moving picture theatres had installed sound-reproducing apparatus.\*

At the same time, the radio grew from the plaything of a few scientifically minded amateurs into a household institution. In November 1920, sponsored only by the enthusiasm of Dr. H. P. Davis, the Westinghouse Laboratories in Pittsburgh made the first commercial broadcast. It was a stunning success and within the year Westinghouse had established station WBZ at Springfield, Massachusetts, WJZ at Newark, and KYW at Chicago. A year later nearly three hundred stations were in operation; by 1929, close to a thousand. The public clamored for receiving sets. Three thousand manufacturers of parts for home assemblies, practically all of them patent pirates, plunged into a maelstrom of competition from which emerged within two short years some forty set-making companies. Such was the tumultuous birth of an industry whose wholesale sales leaped from \$500,000 to over \$400,000,000 in three years.<sup>2</sup> Aladdin himself could not have more miraculously transformed our infant plastics industry than did the enormous demand for parts and housings created by the radio. It literally sopped up the government war surplus of 35,000,000 pounds of phenol.†

Staid, old industries that had matured slowly in the handicraft tradition without the assistance of science or applied research, also began to feel the quickening touch of chemistry. Tanners, soap boilers, paint mixers, glassmakers—all became more chemically minded. In the steel mills the chemists had already won an accepted position, but great progress in the motor-car and machine-tool industries vigorously forwarded the development of alloys, especially ferroalloys, thus emphasizing the chemical aspects of metallurgy.

\* For a fascinating account of this fabulous industry, see Terry Ramsaye's *A Million and One Nights*.

† See Vol. II, p. 137.



In the textile industry the new chemical influences were exerted in two directions. Except for a temporary revival of natural dyestuffs forced by war shortages, coal-tar dyes had already established their supremacy and the principal types of colors for both animal and vegetable fibers had been discovered and applied. The postwar decade was notable for the first large-scale employment of synthetic fibers and for new materials and methods introduced into the dyeing and finishing operations. Both induced new lines of chemical thinking; both enormously increased the consumption of chemicals.<sup>3</sup> During the twenties, American production of rayon increased twelvefold and our imports grew at an even more rapid rate,\* so that by 1929 our textile mills were spinning and weaving over 136,000,000 pounds of synthetic fibers.<sup>4</sup> During the same years, dyes for acetate fibers were perfected; new mordants and detergents were introduced; wetting agents appeared; and processes for moth, mildew, and moistureproofing became prominent.

Textiles had been the first industry to make important use of any synthetic raw materials, the coal-tar dyes, and its alert adoption of synthetic fibers is a shining example of this significant chemico-economic movement. Nevertheless it was really the upstart industries—motor cars, radios, and the movies—that sparked this development during the Booming Twenties. Of these, the automobile made the greatest contributions.<sup>5</sup> To it must be credited not only the first big, industrial market for synthetic lacquers and coated fabrics. It also supplied the motivation of chemical progress in petroleum refining, in rubber compounding, and in metallurgy. The radio, too, created a large-scale industrial market for plastics, lifting them out of the restricted fields of electrical connections and gadgets. The motion picture industry promoted chemical progress in numerous directions by its insistent need for clearer, stronger, nonflammable film and its enormous demand for all sorts of photographic chemicals. Chemical science and chemical industry both responded eagerly to all these exciting influences.

Far beyond the direct influence upon chemical technology and manufacturing, the utterly unparalleled expansion of these three industries dominated the American scene during the 1920's. Their growth, the wonder of wonders of that astonishing era, shoved them into the very forefront of American industrial activity. As opportunities for investment, as employers of labor, as consumers of raw materials, these industries came to occupy key positions. They completely revolutionized American life: they gravely influenced American thinking. The manufacturers of both automobiles and radios made a great contribution to

\* During this period world production of rayons was completely upset, the U. S. taking leadership from Germany and England in 1919, and Italy, previously an inconspicuous producer, advancing to second place in 1925. [See *Nature*, 122, 579 (1928).]

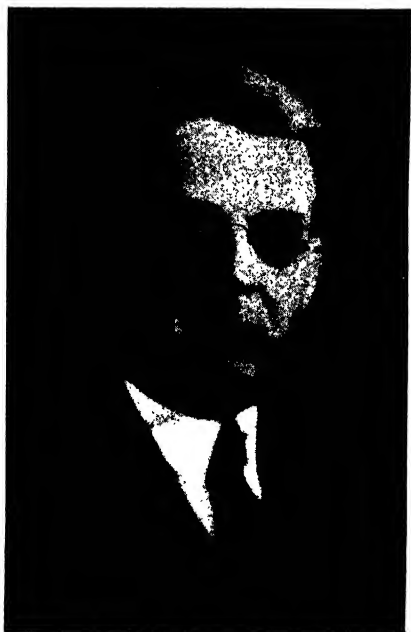


A. CRESSY MORRISON



*Chemical & Metallurgical Engineering*

HOWARD C. PARMELEE



CHARLES N. TURNER



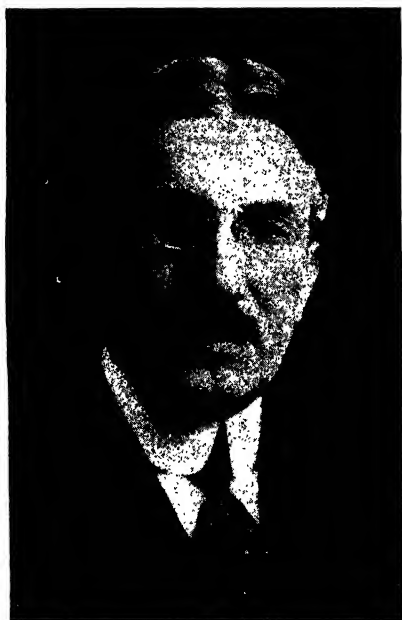
CHARLES C. CONCANNON



MORRIS F. CRASS



PHILIP S. TILDEN



RICHARD SHELDRIK .



GEORGE M. ENO

the business philosophy of abundance, the novel idea of making more money by selling more goods at a lower unit price. In the realm of merchandising they introduced the new technique of mass selling by the partial payment plan.<sup>6</sup> During this wildly expansive decade the automobile, the radio, and the moving picture literally set the pace of living.<sup>7</sup>

The political groundwork of these exuberant years is commonly represented as the heyday of *laissez faire*. On the surface this would appear to be almost self-evident, yet the relationships between government and business during these years continued to confirm the trend toward increased interferences by both with the free play of economic forces. Though checked in its old channels, this control spread out into several new fields like a river dammed.

Direct control over prices and production was dropped at the end of the war, and the attitude of the Government toward business was obviously more friendly than during the Wilson Administration. This was not entirely due to the control of Congress by the Republican party. Influenced favorably by the accomplishments of American industry during the war, the temper of the people had changed, and so long as prosperity reigned lavishly, the man on the street was in the right mood to accept the tenet that what was good for American business was good for the American people. He paid as little attention as did the industrialists, themselves, to critics of the system. Both shut their eyes tightly against plain signs of impending economic difficulties.

Harding had been elected President, pledged to "less Government in business and more business in Government." The slogan was popular. It summed up a growing resentment, sponsored by wartime controls, that Austen Colgate \* had aptly expressed back in 1917, when he was campaigning for United States Senator from New Jersey: <sup>8</sup> "Since its founding 140 years ago, it [the Government] has never been in business until now. The first thing it does is to violate the rules it has made for men in business. . . . The Sherman Law prohibited certain things. In war times, with the Government itself the biggest business force of all, these have become legal, and the change is marked." During the campaign Harding continued rather skillfully to harp upon everyday bread-and-butter subjects, and to make it clear that what he proposed was a return to *status quo ante bellum*, to the political policies of William McKinley, the ideals of Daniel Webster, the economic philosophy of

\* One of five brothers, Austen Colgate went with Colgate & Co., founded by his grandfather in 1806, immediately upon graduation from Yale in 1886. He was for many years active in the political affairs of his state, serving several terms in the Assembly and Senate. A philanthropist, he was vice-pres. of Colgate until his sudden death, Sept. 12, 1927.

Alexander Hamilton. "America's present need," he said in one of his most effective speeches, "is not heroics but healing; not nostrums but normalcy; not revolution but restoration; not surgery but serenity." \* Harding believed quite simply and sincerely in this alliterative jumble of ideas, and while the literary purists twitted him unmercifully over the verbal bastard "normalcy," the word caught popular attention. The people understood what he meant. They elected him and gave him a comfortable working majority in both Senate and House.

Harding made but poor use of his opportunity. He was neither a leader nor a thinker, and the accomplishments of his Administration were due chiefly to three strong, able men in his exceptionally mediocre Cabinet: Charles E. Hughes, State; Andrew Mellon, Treasury; and Herbert Hoover, Commerce. Luckily for himself and his party he died suddenly on August 2, 1923, in San Francisco, just before the atrocious scandals within his official family became public. It appears that until a few weeks before his death he was quite ignorant of the corruption that surrounded him. He never knew but a fraction of all the looseness and dishonesty uncovered in a series of investigations that resulted in the cancellation by the Supreme Court of the Teapot Dome and Elk Hill oil leases; the sentence of his Secretary of the Interior Fall to the penitentiary and the forced resignation of his Secretary of the Navy Denby; the conviction of Charles R. Forbes of the Veterans' Bureau and Alien Property Custodian Thomas W. Miller to federal prison; Attorney General Daugherty's narrow escape from a similar sentence.<sup>9</sup>

Harding's successor, Calvin Coolidge of Massachusetts, was a man of finer homespun qualities; closer woven of purer wool, cut from the traditional New England pattern. He was keen and witty and mentally honest, instinctively cautious and thrifty, with a life-long experience in practical politics. Ideally equipped to carry forward the return to normalcy. Coolidge narrowly missed being one of our great presidents. With a bit more vision and imagination, he might have sensed that the Hamiltonian philosophy to which he and his party subscribed, however valid it might be as a guide to government policy, could no longer be successfully applied to means of traditional Republican practice. He had observed that, except under the abnormal conditions of wartime prosperity, the American standard of living had advanced most substantially during periods when the Government was friendly and co-operative with American industry. His goal was the proverbial "Republican good times." What Coolidge failed to comprehend was

\* Delivered in Boston, May 1920, shortly before the Republican convention had nominated him as a machine-made, compromise candidate for an election that the astute boss of Pennsylvania, Boise Penrose, said prophetically could be won hands down by "any good Republican."

that the First World War had definitely shifted the economic base of the country from an agricultural to an industrial foundation; that in international finance we had moved from a debtor to a creditor position; that the principal source of government income was no longer from tariff duties, but from income taxes. But then few men understood the implications of these obvious facts.

In the Coolidge campaign of cooperation with business, Herbert Hoover played an important part. With him as Secretary, the Department of Commerce briefly assumed the position of leadership which the importance of its domain in American life justifies. Hoover brought to this obscure department the prestige of his reputation as a successful mining engineer and as Food Administrator during World War I. More importantly, he was determined that the Commerce Department should be the official representative in Washington of American business in all of its branches, and that its sole purpose was to further business interests. He moved energetically to put these ideas into effect.

One of Hoover's favorite methods was to encourage trade associations and he sponsored the collection of statistical material and the exchange of open-price information. It was his sincere belief that more accurate, fuller knowledge would make competition less cutthroat and greater stability might be thus achieved. In 1922, 150 of the 1,800 trade associations in the country exchanged open-price information among their members. On the basis of the suit under the Sherman Law against the American Column & Lumber Company, in which the methods of the American Hardwood Manufacturers' Association was an issue, and against the Maple Floor Manufacturers' and Cement Manufacturers' Protective Associations,<sup>10</sup> the Attorney General, although forbidding territory allocation or price fixing, specifically approved the exchange of price information.\* These activities were further endorsed by the passage of the Arbitration Act, February 12, 1925, which made it possible to enforce "gentlemen's agreements," if entered into through trade associations. This was treading on dangerous ground. The very next year, the president of the Chamber of Commerce of the United States, at its annual meeting, warned that American business must regulate itself, or "it will mean more drastic government regulation than we have ever had before or ever dreamed of having."<sup>11</sup>

\* "I am reminded of what we used to refer to as the 'Hoover-Donovan method,' which involved bringing together groups of businessmen to talk with Col. William J. Donovan, then Asst. Atty. Gen. in charge of antimonopoly activities . . . for the purpose of reviewing what these groups might have in mind with regard to common action in any particular industrial or commercial area of interest. No definite decisions or permissions were given, but the practical result of this procedure on the part of the Depts. of Commerce and Justice, cooperating on behalf of business, was highly effective." (C. C. Concannon, to author, Jan. 16, 1946.)

Hoover realized the importance of chemicals and the crucial position occupied by the industry. As early as 1921 he called a group of representatives of the chemical industry to Washington \* to confer on the improvement of the Department's statistical services.<sup>12</sup> To Herbert Hoover statistics were something vivid and vital, and he used them easily and naturally in his thinking and planning, so that he was able to plead most effectively for the publication of complete figures of current production, consumption, and stocks on hand of the basic chemicals. "Sulfuric acid," he said, "is the single, best indicator of general industrial activity. Complete, reliable, up-to-date figures would be not only of great value to you, as a guide in your operations, but also to the entire country."

From time to time the industry had expressed interest in better and more complete statistics. A committee of the American Chemical Society, headed by Dr. Bernhard C. Hesse, had been working with the Department of Commerce to this end. However the executives at this conference received the proposal coolly. They emphasized the extreme complexities of chemical manufacturing. Sulfuric acid with its three types of production—direct manufacture for sale, by-product from smelters, and manufacture for self-consumption—was used as an example of the virtual impossibility of collecting complete, accurate figures. It was agreed, however, that it might be worthwhile to investigate the possibility of collecting adequate statistics on a few basic chemicals: caustic soda, soda ash, and chlorine, sulfuric and acetic acids, benzene, and aniline oil. Because of the acute competitive situation and the localized character of the markets for many heavy chemicals, most companies were hesitant to reveal their actual production figures, and this endeavor came to no tangible end.†

This subject was again broached in May 1925, when Hoover, extending his efforts at cooperation, appointed a chemical advisory committee

\* Attending this meeting were Henry Howard, C. A. Meade, Chas. L. Reese, E. R. Grasselli, August Merz, C. N. Turner, Frank Hemingway, Frank L. McCartney, Salmon W. Wilder, Samuel Isermann, Francis P. Garvan, Howard C. Parmelee, Williams Haynes, the secretaries of the Mfg. Chem. and Synth. Org. Chem. Mfrs. Assoc., John I. Tierney and Wm. R. Corwine, with Carl R. De Long, chief of the Chemical Div., Bur. For. Dom. Com.

† Except for alcohol statistics, based on tax returns to the Treasury Dept., the chemical figures published currently continued to be inaccurate and incomplete. Even the figures of the Dye Census were not above suspicion, and at the time one of the manufacturers of sodium benzoate told me that the total pounds published were not 50% of actual production. The reason was the same that inspired sharp criticism of the prompt publication of our exports and imports, figures: no other nation, not even Great Britain, released and which it was claimed were of damaging help to our foreign competitors. (W. H.)

consisting of A. Cressy Morrison \* of Union Carbide, chairman; Harrison E. Howe, editor of *Industrial & Engineering Chemistry*, secretary; Charles H. Herty, representing dyes; Alfred S. Burdick, Abbott Laboratories, drugs and pharmaceuticals; Henry Howard, Grasselli, heavy chemicals; Gustavus Ober, Jr., fertilizers; Ernest T. Trigg, paint and varnish; Dr. Leo H. Baekeland and Salmon W. Wilder, members at large.<sup>13</sup> At its initial meeting, this committee discussed such timely subjects as the dumping of synthetic methanol by the Germans on our market; the effects upon the fertilizer industry of the recently marketed Leuna-salpeter, a new synthetic nitrogenous fertilizer; the pros and cons of the proposed Stanley Bill making it obligatory for holders of chemical patents to work the process in the United States within two years. Henry Howard suggested that the Department of Commerce invite the leading chemical executives to Washington to an open-house gathering, in order that they might meet the Secretary and his chemical staff and become better acquainted with the services which the Department offered. This suggestion was cordially welcomed by Hoover and Charles C. Concannon,† who had succeeded Carl De Long as chief of the Chemical Division of the Bureau of Foreign and Domestic Commerce. This suggestion bore fruit December 6, 1926, when the first "Chemical Day" was held at the Department of Commerce. More than 150 chemical executives overcrowded the Department's conference room for an all-day session that ended with a dinner in the evening, which Secretary Hoover addressed.<sup>14</sup> The following year, on December 12, the Advisory Committee at its annual meeting added the following members: Frank A. Blair, Centuar Company; Gilbert Colgate, Colgate; Lammot du Pont, du Pont; Charles L. Huisking, Charles L. Huisking & Company; H. C. Parmelee, McGraw-Hill; Frederic Rosengarten,

\* An active, life-long protagonist of protection, Cressy Morrison, born in Wrentham, Mass., Dec. 6, 1864, was associated with Union Carbide and Carbon since 1906 till his retirement in 1930. He filled many official positions: Nat. Res. Council (exec. bd.), Am. Museum Natural Hist. (chmn., Comm. on Astronomy & Planetarium), N. Y. Acad. Sci. (pres., 1938-39), Nat. Assoc. Mfrs. (Tariff Comm.), Internat. Acetylene Assoc. (secy-treas., 1906-31), Compressed Gas Mfrs. Assoc. (pres.), Am. Tariff League (chmn., exec. comm., 1927-37), Synth. Org. Chem. Mfrs. Assoc. (bd. gov., 1927-30), Mfg. Chem. Assoc. He was chmn., Fin. Comm. of the Am. Chem. Ind. Tercentenary, 1935; author of *Man in the Chemical World* and *Baking Powder Controversy*, 2 v.; comp. of *Encyclopedia of Superstition*, 3 v.

† Charlie Concannon entered upon his long, valuable career as "chemical man" of the Dept. Com. in 1922. He was born in Boston, Mar. 13, 1889, educated at the Boston Latin Sch. and Harvard (A.B., 1911), whence he joined the sales staff of Brewer & Co., Worcester, Mass., later becoming mgr. of Takamine Lab. He was one of the first to recognize the value of naturalizing the tung oil tree in the South and has long been an ardent supporter of developing closer chemical business relations with South America. He has represented the Government and the industry at innumerable important conferences, notably as chmn. of U. S. delegates to the 10th Internat. Cong. Chem., Rome, 1938.



Merck; J. T. Skelly, Hercules Powder; and Walter C. Teagle, Standard Oil (New Jersey).<sup>15</sup>

A second general conference was held in Washington, February 16, 1928, "to consider together present world conditions as they affect the American chemical industry, to learn from bureau and division chiefs the details as to service now available, to inform the Department as to needs of the industry, and to discuss further cooperation between the Department and the industry."<sup>16</sup> It was attended by over 300 executives, the most important group of chemical men that had ever been gathered together, and every subject on the agenda was discussed by experts.\* A. Cressy Morrison, as chairman of the Chemical Advisory Committee, presided, and the luncheon was addressed by Assistant Attorney General Donovan. The conference suffered from the absence of Hoover, who was involved in helping to settle the coal strike. The banquet had to be canceled, and though the conference concentrated on foreign cartels and export trade, it brought out the extreme diversity of interests in the chemical industry. This was revealed in the comments reported on the resolution offered by Salmon W. Wilder of the Merrimac Chemical Company, calling upon the Department of Commerce to make a complete, comparative study of all chemical production costs in all competing countries.

"A large order that," commented an alcohol manufacturer, and an alkali sales manager added, "And an expensive one to fill."

"But," as a maker of pharmaceuticals pointed out, "neither alcohol nor alkali suffers greatly from foreign competition."<sup>17</sup>

Direct assistance to American industry in foreign fields was continued by the Department and Hoover was at pains to strengthen the Bureau of Foreign and Domestic Commerce. In 1921 he selected as its director the suave, energetic, highly trained economist, Dr. Julius Klein. The Department collected and kept up-to-date the credit ratings of 280,000 business firms throughout the world, and could get by cable within 48 hours additional or supplementary information.<sup>18</sup> The Chemical Division vigorously combatted the various foreign monopolistic controls of essential raw materials. A world-wide nitrogen survey was published in 1924 and two years later a similar study was made of potash, pointing out the significance of the German-French sales agreements and the need of developing domestic sources of this key element. Quinine, iodine, and camphor were subjected to the same scrutiny and the findings publicized.

At the same time a major operation was performed on the basic

\* Concannon and Klein, of the Dept. Com.; Ray M. Hudson, Bur. Stand. on simplification of grades and styles and containers; Delahanty on chemical exports; Daugherty on the German chemical industry; Reagan on the French chemical industry.

organization of the Department. Previously the work and personnel had been predicated upon a geographical foundation. Hoover changed this, and the old area framework was replaced by commodity divisions presided over by men with industrial experience and staffed by workers who knew chemicals or whatever the commodity involved might be.<sup>19</sup> In advancing this commodity philosophy, Thomas W. Delahanty \* was appointed as assistant to Concannon in the Chemical Division. In 1927 the staff was increased and shortly afterwards William J. Wizeman became a second assistant to the Division chief. Klein overhauled the foreign staff, and their reports under his directorship set a high mark of excellence and variety.† At the suggestion of the Chemical Advisory Committee, a conference of these European representatives was held in Paris, the first week of August 1929. It was headed by Concannon, and Dr. Lewis H. Marks, then executive secretary of the Industrial Alcohol Institute, and Charles J. Brand, secretary of the National Fertilizer Association,<sup>20</sup> who conferred with the representatives from Paris, Berlin, London, Rome, Warsaw, and Berne, discussing current conditions, particularly the growth of cartels and the ability of American export associations effectively to meet their competition. As an outgrowth of this Paris conference, the foreign representatives of the Department of Commerce were brought back to this country for a series of "chemical day" conferences in New York.<sup>21</sup>

This sharp interest in foreign trade, born of the export business enjoyed during the war, emphasized the novel features of the new Tariff Act—the antidumping and flexible schedules provisions—and the knotty problem of the war loans. The President and the Tariff Commission were time after time memorialized to invoke the embargo or to raise specific schedules.‡ The flexible provisions of the Tariff Act of 1922 (section 315)§ did not escape legal question as to their constitutionality. This was finally answered by the decision of the Supreme Court in the case of the J. W. Hampton, Jr., & Company, over the proclamation of the President, May 19, 1924, increasing the duty on barium dioxide from 4¢ to 6¢ a pound, which upheld the decision of the Court of Customs Appeals. This change in tariff rates by Presidential proclamation was within the powers of the Chief Executive as authorized by law and the Constitution.<sup>22</sup>

\* Delahanty had been an inspector for the Ordn. Dept. and a Lt. (j.g.) in the Navy Air Corps during the First World War. He had business experience as chem. broker with J. E. McGoldrick and as mgr. of the Trading Dept. of Dicks, David Co. He was born in N. Y. City, Feb. 19, 1892, and educated at Cornell (B.Ch., 1917).

† Conspicuous among these foreign representatives for their chemical reports were Wm. T. Daugherty, Berlin; H. S. Fox, London; D. J. Reagan, Paris; C. E. Lyon, Berne; Elizabeth Humes, Rome; A. Viola Smith, Shanghai.

‡ For details, see specific cases, as methanol, cresylic acid, etc.

§ For rates, see Vol. II, Appendix V.

The practical matter of determining costs abroad and in this country, upon which the President was authorized to change rates to equalize unfavorable differences, also reached the Supreme Court in this country. Abroad it raised a diplomatic tempest. Whether a manufacturer's costs are a "trade secret" and whether an importer has the right to inspect such figures when filed with the Tariff Commission came to a head when the American Nitrogen Products Company of Seattle petitioned for an increase in the rates on sodium nitrite. This case was in the courts till 1933. The American Nitrogen Products Company revealed cost data to the Tariff Commission after a pledge of secrecy. The Norwegian Nitrogen Products Company, importers, demanded these cost data of the domestic producer and the right to cross-examine its officers, at the same time refusing to give up its own cost figures. The Commission denied these requests and the importer appealed the case. Meanwhile President Coolidge raised the duty from 3 cents to 4½ cents a pound and the Supreme Court refused to hear the case as a moot question. The Norwegian Nitrogen Products then attacked the appraisals upon which the President had raised the rate on sodium nitrite. The Customs Court and the Customs Court of Appeals upheld the contention of the Tariff Commission that unless cost and price information were held inviolate by them, it would be utterly impossible to administer the flexible provisions. The case reached the Supreme Court which by a six-to-two decision upheld the legality of the President's rates and the Commission's ruling.<sup>23</sup>

When Secretary of the Treasury Mellon issued an order that duties on all dyes manufactured by Durand & Huguenin of Basel were to be levied at American valuation, because the Swiss firm had refused American customs agents access to its works or records, a sharp diplomatic protest was filed through the legation at Berne.<sup>24</sup> The Swiss Government intimated rather pointedly that, unless such unwarranted "fishing expeditions" into the well-recognized trade secrets of its citizens ceased, it would be compelled to ask the representatives of the Treasury Department to leave the country. This stand naturally received covert official support in London, Paris, and Berlin. Far from retreating, Secretary Mellon asked the State Department to appoint these tariff representatives its customs agents and so give them diplomatic standing and immunity from deportation. An international incident was sidestepped. The matter was tacitly left to the discretion of the individual foreign manufacturers. Generally they found it expedient to welcome these unwelcome visitors rather than pay tariff rates based on American valuation.\*

\* "One of the most important things that happened in the American chemical industry was the introduction of American valuation in the Fordney-McCumber Tariff,

The foreign policies of both Harding and Coolidge were aimed at two major objectives: to support actively the American business position abroad and to promote world peace. At the Washington Naval Conference, called by Harding, the United States had taken the lead in reducing naval armaments and this was followed by similar conferences at Geneva and London. The Briand-Kellogg Pact, signed April 6, 1927, outlawing war between France and the United States, was widely hailed at the time and similar pacts between Great Britain, France, Germany, Italy, Japan, and the United States were signed. Though the language outlawing war was perfectly clear, there was no positive implementation for peace. More realistic, and at times unpleasantly roughshod, was the commercial policy adopted in the Caribbean, South America, and China, where the popular musical comedy quip, "the cocktail follows the flag," was frequently translated literally into "the Marines follow the dollar."

In line with the return of normalcy, the financial policy of the Government during these years sought to reduce taxes and the public debt. Pursuing this path, Andrew Mellon was so successful that he earned the title of "the greatest Secretary of the Treasury since Alexander Hamilton." His accomplishments were indeed impressive. Within three years after the war, taxes had been reduced a third, chiefly in the excess profits and income schedules. At its peak in 1919, the public debt was \$25,700,000,000. By 1928 this had been reduced to \$17,318,000,000 and there was a surplus in the Treasury of \$400,000,000. Against this debt stood the indebtedness to us of eighteen foreign governments, which after numerous downward readjustments, was \$11,000,000,000. Except for France, Greece, Czechoslovakia, and Yugoslavia, these war debts had all been renegotiated on the basis of gold bonds, and while from the point of view of the American taxpayer the final settlements had been more than generous, Coolidge and Mellon believed these obligations of our late Allies represented tangible assets in collectable form. They were turning over to the incoming Hoover Administration a war indebtedness which had been reduced four-fifths. At least so they thought, for nobody could then foresee that within the next few years not only Latvia, Estonia, and Rumania, but Belgium, Italy, and Great Britain would repudiate these bonds.<sup>25</sup>

During the Booming Twenties, the American people at large had also acquired a great portfolio of European investments, a total of over

that is, valuing imports at American wholesale prices instead of the old method (still in force) of valuing imports at the wholesale market value at the time of shipment in the country of origin. Frauds committed in false valuation, which cannot be checked, are flagrant, but with only six representatives throughout the world checking all imports, a correct check was, and still is, impossible." (A. Cressy Morrison, to author, Apr. 10, 1946.)

\$7,000,000,000 in stocks and bonds and a similar sum in tangible property. In effect, we had financed the reconstruction of Europe to a total somewhat greater than our own war debt. When the world-wide financial debacle came in 1929, we not only had to liquidate our own inflation, but to write off some \$26,000,000,000 of foreign investments.

## REFERENCES

1. Pound, *Turning Wheel*, p. 216. For the growth of the automobile industry, see also Epstein, *Automobile Industry*; Merz, *And Then Came Ford*; Gibson, *The Motor Car and Its Story*; and specifically, Glover and Cornell, *Development of American Industries*, p. 68.
2. Glover and Cornell, *op. cit.* pp. 835-46.
3. *Chem. Met. Eng.* 35, 585 (1928); C. F. Mullin, *Ind. Eng. Chem.* 22, 461 (1930); S. B. Hunt, *Chem. Ind.* 43, 140 (1938).
4. *Drug Chem. Mkts.* 12, 845 (1923); *Textile Organon* 16 (Jan. 1934); Dept. Agr., *Agr. Inform. Circ. No. 64*, 9 (1944).
5. *Chem. Met. Eng.* 34, 275 (1927); *Chem. Mkts.* 20, 991 (1927); L. B. Case, *ibid.* 24, 475 (1929).
6. For contemporary study of these developments, see Seligman, *Economics of Installment Selling*.
7. L. L. Barnard, *Am. J. Sociol.* 29, 1 (1923).
8. *Drug Chem. Mkts.* 13 (Dec. 26, 1917).
9. *O.P.D. Repr.* 72 (Feb. 14, 1927); 20 (Mar. 14, 1927).
10. *Drug Chem. Mkts.* 10, 17 (1922); 16, 1632 (1925).
11. Malin, *United States After the World War*, p. 89; see also Fed. Trade Comm., "Open-Trade Associations," Sen. Doc. 226 (70:2), 1929.
12. *Drug Chem. Mkts.* 8, 1095, 1146 (1921); *O.P.D. Repr.* 55 (May 23, 1921).
13. *Ind. Eng. Chem.* 17, 628 (1925); *Drug Chem. Mkts.* 16, 1555 (1925).
14. W. Haynes, *Chem. Mkts.* 19, 1273 (1926); *O.P.D. Repr.* 21 (Dec. 13, 1926); *Chem. Met. Eng.* 33, 770 (1926).
15. *Chem. Met. Eng.* 34, 769 (1927); *Chem. Mkts.* 21, 847 (1927).
16. Invitation to the conference.
17. *Chem. Mkts.* 22, 305 (1928).
18. A. Cressy Morrison, to author, May 10, 1946.
19. C. C. Concannon, to author, Jan. 21, 1946; *Chem. Mkts.* 20, 307 (1927), 21, 848 (1927).
20. *Chem. Mkts.* 25, 177, 295 (1929).
21. *Ibid.* 627; *O.P.D. Repr.* 45 (Dec. 16, 1929).
22. *Drug Chem. Mkts.* 18, 1283 (1926); *Chem. Mkts.* 20, 323, 824 (1927); *Chem. Met. Eng.* 34, 186, 645 (1927), 35, 250 (1928).
23. *Chem. Met. Eng.* 34, 265 (1927); *O.P.D. Repr.* 21 (Sept. 5, 1927), 17 (Feb. 13, 1933).
24. *Drug Chem. Mkts.* 16, 1171, 1177 (1925). For French view, see E. Neron, *Drug Chem. Mkts.* 18, 391 (1926).
25. Clark, *Costs of the World War to the American People*; E. Davis, *Current Hist.* 35, 643 (1932). See also Jennings, *History of Economic and Social Progress of the American People*, pp. 722-25; Shannon, *Economic History of the People of the United States*, pp. 853-58.

## Chapter 2

### THE STATE OF TRADE

CHEMICALS PASS WARTIME PRODUCTION LEVELS—NEW CHEMICAL PRODUCTS COMPETE WITH OLD AS MASS PRODUCTION METHODS ARE PERFECTED—PRICE CUTTING AND “PROTECTION-AGAINST-DECLINE” IN SALES CONTRACTS DEMORALIZE MARKET—COMPETITION FORCES REVISED SELLING ORGANIZATIONS, IMPROVED ADVERTISING, AND TECHNICAL SALES SERVICE—CHEMICAL EXPANSION SOUTHWARD AND WESTWARD.

**R**ECOVERING SPEEDILY from the setback of 1919-21, the American chemical industry within three years passed many of the phenomenal production records made under the stimulus of World War I. During the Booming Twenties it virtually doubled both its resources and its output.

Between 1921 and 1929, the value of chemical and allied products, as recorded by the Census, jumped from two and a quarter billion to almost four billion dollars.\* During the same years the number of establishments increased from 7,348 to 8,278. None of these figures are to be taken too literally. Like any definition of this highly ramified industry, the classification “Chemicals and Allied Products” is debatable, and in expressing production in terms of sales, dollars may so overshadow pounds that the result becomes quite deceptive.

Closer to the core of strictly chemical manufacturing enterprise than these “blanket figures” are the actual statistics of the most representative of all chemicals, sulfuric acid, which measure most accurately actual plant operations of the entire group. In 1921 the output of 50° Bé. acid was 4,369,941; in 1929, 8,491,114 short tons.<sup>1</sup> The current price quotations on 66° acid in carboys—\$20 per 100 pounds in 1921 and \$16 in 1929—are also exceedingly illuminating. The decline in the number of acid makers from 197 to 170 pictures more truly what happened throughout the industry: the elimination of weak companies and the combination of many into mergers.

As the world's greatest producer of chemicals, the United States strengthened its firm grip on first place. In 1927 the German expert, Dr. C. Ungewitter, reported <sup>2</sup> to the International Economic Conference of

\* For the Census statistics of the chemical and related industries covering the years 1921-29, see Appendix II and III; for high-low prices, IV; for imports and exports, V and VI. See also *Chem. Met. Eng.* 46, 543 (1939); Fabricant, *Output of Manufacturing Industries, 1899-1927*.

the League of Nations, that in 1913 the United States accounted for 34 per cent of the world's chemical production, Germany, 24 per cent, followed by Great Britain and France. The order remained the same in 1925, but the American share had risen to 47 per cent, and Germany's had fallen to 17 per cent.\* To return to the more tangible sulfuric acid statistics, before the war American output did not quite equal the combined production of Great Britain and Germany, then our nearest rivals.<sup>3</sup> By 1925 it had doubled and was greater than the combined output of France, Germany, Great Britain, and Italy, which followed in the order named.

In world markets this country continued to be incomparably the largest buyer of chemicals. As an exporter, however, it was estimated that from a prewar position of fourth, shared with France and behind Germany, Great Britain, and Chile,† we had advanced to second place behind Germany. During the war we had captured a share of the world trade roughly equivalent to that held by Great Britain before the war.‡

The domestic base of our chemical dominance was very broad: an enormous market and abundant raw materials. The American people were the world's largest consumers of almost every conceivable kind of goods from milk to locomotives, and our richly endowed land furnished most materials essential for modern industry. Save for nitrogen and potassium, we had superabundant supplies of all the needed chemical elements. Of the three basic raw materials of heavy chemical manufacture—salt, lime, and sulfur—stores of the first two were so boundless, no one even thought of estimating our reserves, and we were producing 80 per cent of the world's brimstone. In 1926 we produced 65 per cent of the world's supply of naval stores, 62 per cent of petroleum, 45 per cent of barytes, 42 per cent of phosphate rock. These are important

\* In its famous reviews of world chemical trade the Dresdner Bank credited U. S. with 45.4% of world production in 1924 and 45.8% in 1928. [See *Chem. Age (London)* 23, 112 (1930).]

† Chile sent into world chemical trade sodium nitrate and crude iodine, both natural monopolies.

‡ As estimated by Ungewitter, the percentage share in world chemical trade of the 5 principal exporting countries was:

	1925	1913
Germany	23	28
United States	16	10
Great Britain	14	16
France	13	10
Chile	11	15

Assuming the percentages are based upon the value of chemical exports, I should raise the figure somewhat for Germany prewar and lower considerably its 1925 share in world markets. I should also increase the postwar figure for Great Britain and decrease that of Chile, which by 1925 had probably been replaced by Italy and possibly also by Japan. (W. H.)

chemical assets. We are scarcely less rich in metal resources, and at that time our output of zinc was 64 per cent of the world total; of iron and copper, more than half. We were producing 52 per cent of the world's timber; 43 per cent of the world's coal; 65 per cent of the world's steel; 55 per cent of all cotton.<sup>4</sup>

Equipped from this arsenal of raw materials, nourished by an enormously expanding consumer demand, the American chemical industry grew to dominating size. During the first quarter of the century it scored a 500 per cent gain in production. Chemical imports increased 300 per cent. Exports, though only half the value of our chemical purchases abroad and but a little more than five per cent of the domestic output, increased 400 per cent.<sup>5</sup> The rate of growth, which since the Civil War had been consistently about 50 per cent for each successive decade, had been spurred forward by the demands of World War I, when in four years chemical output doubled.\* The quick, decisive contraction of 1920 established a new base from which, during the 1920's, growth was resumed at a rate almost twice as fast as during the previous half century.

This change of pace is significant. It was made possible, as we have noticed, by the industrial growth of the country, notably in the automobile, radio, textile, and paper industries;<sup>6</sup> by the commercial introduction of synthetic fibers and plastics.<sup>7</sup> This accelerated expansion conditioned all chemical activities. It was the mainspring of progress. It was also the root of new evils and the cause of new problems.

These piping times of prosperity were not all beer and skittles. Though markets expanded rapidly, production of chemicals kept pace and competition was razor-keen. The competitive battle was continually shifting its frontlines. The new industries insistently demanded great qualities of many familiar chemicals, but they ignored others, thus throwing out of plumb the very cornerstones of the industry. Sulfuric and acetic acids, alcohol, acetone, caustic soda, bleaching powder, phenol, and bromine were all profoundly disturbed during this period. At the same time, an extraordinary number of new chemicals came on the market. Some of these were developed in direct response to the demands of new applications. But by far the majority came into head-on competition with established rivals.

Finally the increased rate of output fostered a sensational perfection of the continuous, automatic chemical process. Lessons learned in the forced wartime production were applied and extended. Mass production on a large scale entered the chemical industry. It introduced new techniques into production; into competition, an entirely new concept.

\* Value of chemical products: 1914, \$158,054,000; 1919, \$574,141,000; which should be adjusted for volume by the advance of prices during these years.



Years later, Garett Garrett phrased this aptly when he wrote "cost has become a function of quantity."<sup>8</sup> Heretofore progress in chemical manufacturing had come from two types of technical improvements: new processes that made it possible to employ cheaper, more available raw materials; new methods that raised the yield or the quality of the principal products or else increased the value of by-products. Supplementing these historic means of reducing the cost of chemicals, mass production injected another disrupting element into the competitive situation.\* The lower costs it achieved were quickly translated into lower prices and the continuous automatic process thus became an important contributor to another phenomenal record which the chemical industry made during this period. Against almost irresistible inflationary influences which advanced wages, interest rates, and the prices of raw materials, agricultural products, and finished consumer goods, the prices of chemicals scored an almost continuous decline during these expansive years.

This economic feat threw into bold relief the distinctive characteristics of chemical marketing and the evils peculiar to chemical competition.† Since chemicals are industrial commodities, their prices are never fixed as is the price of an automobile or a packet of cigarettes. They are not as delicately responsive to supply and demand as the quotations of the stock market or the grain pit, yet they react more promptly to these influences than do most manufactured goods. Unfortunately for the stability of the chemical market, the force of demand is slow-moving and beyond the control of the chemical manufacturer, while supply changes quickly and markedly on the basis of chemical plant operations.

The cost of the chemicals involved in the manufacture of consumer goods—the dyes in a suit of clothes or the alum in a ton of paper—is but a tiny fraction of the total manufacturing expense. The cost of wool or wood pulp is so important an element in the price of cloth or paper that it influences a manufacturer to stock up or hold off. But his purchases of dyes and alum, based as they are upon the requirements of his production schedule, will continue regardless of price fluctuations. Having no control whatsoever over the consumption of cloth or paper, manufacturers of these chemicals are forced to adjust supply to demand by price changes. Thus the familiar experience that a new producer of

\* The classic exposition of the theory of mass production of chemical products is the Perkin medal acceptance speech of Dr. Herbert H. Dow. [See *Ind. Eng. Chem.* 22, 113 (1930).]

† For the economics of chemical price making and competition, see W. M. Rand, *Chem. Met. Eng.* 36, 6 (1929); L. W. Bas, *ibid.* 37, 409 (1930); Tyler, *Chemical Engineering Economics*, p. 62; Haynes, *Chemical Economics*, Chap. 4; Hempel, *Economics of Chemical Industries*, Chap. 9.

chemicals is compelled willy-nilly to "cut his way into the market." The result is an economic paradox: though price has but little effect upon chemical demand, nevertheless it must assume the major task of reestablishing any unbalance of the market.

Emphasis upon price is accented by the fact that most chemicals are sold in thoroughly standardized grades. Be it soda ash or berberine hydrochloride, the products of different manufacturers differ so slightly that from the consumer's point of view they are interchangeable. While chemical producers make the most of distinctive packaging, claims of prompt delivery, and offers of technical service as sales arguments for their own goods, still price remains the focal point of competition. Even in the most stable markets this is true, and during a period when supply either markedly expands or contracts, price becomes the paramount consideration.<sup>9</sup>

Throughout the first half of the 1920's the surplus capacity built during the war was a constant temptation to many chemical manufacturers to keep this invested capital at work and so achieve the economies of large-scale production. Each one who succumbed to this plausible industrial logic was forced to get, by hook or crook, more than what might be called his fair share of the market. Accordingly, these years were characterized by continuous, aggressive price cutting. The winter of 1925-26 furnished some apt examples of these principles. The mild weather slackened the demand for anti-freeze and the price of methanol was slashed. Invasion of the New England territory by an old producer of ammonia resulted in a savage price war, and the Philadelphia alum market suffered the same disturbance from the same cause.<sup>10</sup>

During the latter half of this decade, the national demand for chemicals overtook the war-expanded supply. At this point, however, new products and new processes began to upset the equilibrium seriously. Technological advances led to numerous price reductions.\* Thus throughout the entire period competition was upset, in certain instances revolutionized, furnishing the chief motive for the chemical activities of these years.

Although the distinctive economic conditions surrounding the production and distribution of chemicals conspire to foment price fluctua-

\* Price cutting and price reduction have been clearly defined by Wm. M. Rand: "Price cutting is differentiated from price reduction in that it carries with it the idea that the price cutter, in order to obtain the business of his competitors, will sell at a lower margin of profit. Price reduction indicates that the entire industry, on account of lower costs, has reduced the price. Price reduction is constructive; price cutting, destructive. Price cutting may change the time of buying or the source of supply, but it creates no new business. . . . Revolutionary price changes are usually the result of technologic advances. In our age of chemistry discoveries of new methods of manufacture are constantly being made. These discoveries materially affect the volume of business." [See *Chem. Met. Eng.* 36, 6 (1929).]

tions, stability in the chemical market is a prime requirement of both producers and consumers. Chemical manufacturing involves notably heavy investments in apparatus, subject to high obsolescence due to both the excessive wear and tear of chemical processing and the rapid advances in chemical techniques. It also demands of the chemical maker long-time commitments for the purchase of raw materials and the employment of a trained operating staff. Shutdowns are exceptionally costly, placing an additional premium on steady production. On the other hand, the chemical consumer is less concerned with the cost of his chemicals than he is with the assurance of prompt delivery in adequate quantities of the correct grade to meet his requirements.

To assure makers of chemicals an unequivocal market and chemical users a reliable supply, the device of selling chemicals on contract for future delivery at a prearranged price was early adopted. It served this purpose admirably. Not only did it give both parties the assurance each needed, but by putting a stout platform under the whole chemical price structure, it gave stability to this large, varied group of widely used essential industrial raw materials.

During the First World War, a number of influences seriously impaired the sanctity of sales contracts. For many years the American mind had been swinging away from principles to what is curiously called the practical, as a guide to conduct; from the lodestone of what is right to the weather vane of what is expedient.\* Nowhere was this change more manifest than in the everyday affairs of American business. In the chemical industry during World War I, the speculative orgy of the irresponsible dealers and brokers who elbowed their way into the trade and the emasculation of the sales contract by the protection-against-decline clause were signals of this lowering morale.† The speculative episode was brief, a phase that ended when the close of the war erased its opportunities. Nevertheless it left marks on the industry. Its abuses prompted American chemical manufacturers to take control of distribution by organizing their own sales departments. Protection against decline persisted and it introduced insecurities for which the industry paid dearly in the price crash of 1930.

The essential unsoundness of guaranteeing the buyer safety against price declines was early recognized. Palpably it transformed a positive commitment for the maker to deliver and the user to accept and pay for a definite quantity at a known price, into a seller's option on a quantity loosely defined as "buyer's requirements" at a price that could not ad-

\* This theme has inspired an enormous literature. For a variety of representative modern approaches, see Adams, *Degradation of the Democratic Dogma*; Rourke, *Roots of American Culture*; Perry, *Puritanism and Democracy*; Mumford, *Condition of Man*.

† See Vol. III, pp. 421-23.

vance, but which must be lowered in the event of any decline in the market. The practice had spread to other industries, and in 1925 the Federal Trade Commission, in a test case, charged three soap companies with unfair trade practices because they offered price protection to large buyers. The case was dismissed, but two of the Commissioners, Nugent and Thompson, registered a vigorous minority protest in which they indicated clearly the evils involved. They emphasized the essential injustice that in a rising market the buyer gets the profits, while in a falling market the seller pays the losses. More broadly they pointed out that a price guaranteed against decline encourages overbuying and speculation on the part of buyers, while on the part of sellers, it furnishes a strong incentive to hold up spot prices artificially. Finally it increases the market influence of a few large producers.<sup>11</sup>

These concomitants were self-evident in chemical circles and their effects particularly baneful. It is likely, therefore, that the practice would have been abandoned had it not been that for five or six years a surplus capacity hung like a sword of Damocles over the chemical market. The efforts of chemical makers to employ their war-built facilities created an almost chronic oversupply of most chemicals. A buyers' market resulted in which the purchaser could dictate his own terms, and a single, important producer, willing to guarantee against price decline, forced his competitors to do likewise.

One concerted, cooperative effort was made to eliminate the price-protection clause in chemical contracts. The National Association of Purchasing Agents, which at this time was endeavoring to standardize buying practices by introducing uniform contracts, had expressed its disapproval of the principle of guaranteeing prices. Acting upon this suggestion, a joint committee was formed by the Manufacturing Chemists' Association and the Salesmen's Association of the American Chemical Industry. The manufacturers' committee consisted of P. Samuel Rigney of Roessler & Hasslacher, chairman, Charles M. Butterworth of Pennsylvania Salt, George Eno of Grasselli, Albert W. Hawkes of General Chemical, Frank L. McCartney of Monsanto, J. H. D. Rodier of Grasselli, Charles N. Turner of Newport, Milton C. Whitaker of U. S. Industrial Alcohol, and Salmon W. Wilder of Merrimac. On the salesmen's committee served John A. Kienle, Mathieson Alkali, chairman, John A. Chew of Warner, Philip M. Dinkins of Kalbfleisch, Edward J. Barber of White Tar, John W. Boyer of Mathieson Alkali, Ralph E. Dorland of Dow, Williams Haynes of *Drug & Chemical Markets*, and Philip S. Tilden of du Pont.<sup>12</sup>

With the advice of legal counsel from leading companies, this joint committee, after two months' deliberation, submitted a report and a

model, uniform contract.\* This followed the standardized form of the coal and iron contracts approved by the Purchasing Agents and the Department of Commerce. Its provisions covering terms of payment and of delivery were those generally in force at the time among chemical manufacturers. It omitted any clause guaranteeing protection against price decline and substituted exact quantities for the illusive phrase "buyers' requirements." Adoption by all producers was obviously a prerequisite to the successful adoption of any standardized contract and its failure was forecast when, acting on the advice of legal counsel that agreement on terms of sale might be interpreted as a violation of the anti-trust laws, the General Chemical Company instructed Hawkes not to sign this report and the other members of the Allied group indicated their unwillingness to enter into any agreement over a uniform sales instrument.

During the early 1920's spasmodic, individualistic efforts were made to curb price cutting that was rife in this buyers' market. Under such conditions, current quotations are notoriously apt to be higher than the prices at which sales are being consummated. Although the chemical business papers were well aware of this situation, they were unable to correct it however sincerely they might believe that prompt publication of accurate prices was not only their duty, but a positive advantage to both sellers and buyers. Convinced that dependable price information would discourage price cutting by making it difficult for a buyer to play one seller against the other, one of the trade papers instituted a campaign for "open prices openly determined."<sup>13</sup>

During the years of excessive competition that followed the end of the war, the sales contract was further weakened in the less-than-carload market. Here local distributors, acting commonly as recognized sales agents of manufacturers, were supplied chemicals in carlots, selling in less-than-carload quantities within their defined territory. Much of this local business was handled on contracts between the distributor and local buyers. Most of these contracts were for a variety of products, covering the chemical needs of small consumers of all types. Quantities ranged from a single drum or so a month to several units a week, delivered at the door of the consumer. Some 30 to 40 per cent of the total tonnage of industrial chemicals consumed in the country were sold through these channels.

When competition among the local distributors became super-keen, they frequently employed the standard grades of widely used chemicals—the alkalies were favorites—as the grocer used sugar, as bait to secure the contract business of prospective customers. Price cutting of this

\* For full text of the report and model form, see Appendix VII.

kind was progressive. It went on until it threatened to disturb the entire price structure, since the price for small lots delivered was whittled down to the figure at which the contract buyers, dealing direct with the manufacturers, were buying. Naturally these larger consumers protested, invoking the protection-against-decline clause. The volume of these local sales was quite sufficient seriously to affect the gross business of makers and thus the local situation became an element in their own competition. Since the most aggressive price cutters often accumulated a large percentage of the business in their territory and as they sometimes bought outright on contract and claimed the right to resell at whatever price they chose, the control of prices virtually passed from the makers to the jobbers.\*

The Mathieson Alkali Works, which since the war had been building up its own sales force, carried its own warehouse stocks for local delivery at many points. It endeavored in 1922 to clarify this confused situation by taking full-page ads in the chemical trade papers,<sup>14</sup> announcing a complete schedule of prices for less-than-carload quantities. This schedule, based on the differences in freight charges, was very complete. It quoted on the basis of 100 pounds delivered to the buyer's plant in twelve different cities from New York to St. Paul, Kansas City to New Orleans. It covered light soda ash in bags and barrels and dense ash in barrels; solid and ground caustic soda in drums and flaked caustic in barrels; bicarbonate of soda in barrels and kegs; bleaching powder in 800 and 300-pound drums; and liquid chlorine in cylinders.

A couple of years later when the market for calcium arsenate was completely disorganized during two successive years,<sup>†</sup> a similar effort was made by the General Chemical Company. It published a schedule of established differential prices at various important consuming points throughout the South. Neither of these individualistic attempts was successful. In fact, open publication of these price schedules only set up a target at which price cutters shot with more deadly accuracy. Nevertheless, they were not without some wholesome effect.

Much of the market demoralization was stirred up by purchasing agents who skillfully played one salesman against the other. So long as the seller, always anxious to cultivate the buyer, was ready to believe the worst of his competitors, these tactics worked all too well. They were offset to some degree by a number of organizations which brought salesmen together, establishing personal contacts and some measure of mutual confidence and respect. Especially active at this time was the Salesmen's Association of the American Chemical Industry which held

\* For the dealers' side of this problem, see J. K. Coyne, *Drug Chem. Mkts.* 14, 929 (1924); C. T. Thompson, *Chem. Mkts.* 19, 1023 (1926).

† For details, see Chap. 7.

monthly dinner meetings with good speakers, including such authorities as General Amos A. Fries, head of the Chemical Warfare Service; R. E. M. Cowie, vice-president of the American Railway Express Company; and the marketing specialist, J. George Frederick. There were also spring and fall outings, three golf tournaments during the summer, and an annual Christmas party which has become the traditional jollification of the industry.\* While its activities were centered in New York, the historic Drysalter's Club in Boston, the Chemical Clubs in Philadelphia, Chicago, Cleveland, and Providence, the Druachem Club in New York all served similar social purposes. At this time, too, a number of informal, so-called "Dutch Treat Clubs" were popular luncheon gatherings of salesmen and local distributors in a number of cities.

Out of the disturbed market conditions of the early twenties also grew the movement to keep sales disputes out of court by submitting them to arbitration. Backed by strong endorsement from the Department of Commerce, the Arbitration Society of America secured the passage of legislation in many states giving the effect of law to the decisions of properly appointed arbitrators and it worked through various industries to further the practice. At the Society's invitation, a group of leading chemical men met at luncheon at the Lawyers' Club in New York, May 27, 1925. A committee was appointed, consisting of Robert T. Baldwin, H. S. Farleigh, Williams Haynes, P. Samuel Rigney, and B. R. Tunison. Again the results proved to be only indirect and educational, for no concerted, industry-wide action was taken.<sup>15</sup>

Other symptoms of the keenness of competition continued to appear. Difficulties in the enforcement of charges made to customers for returnable containers was a constant source of friction. This was an old problem, dating back to when the early acid makers in England delivered in balloon-shaped, 13-gallon bottles, enclosed for protection in a wicker hamper.

It was obviously to the advantage of the consumer that the chemical manufacturer recover and re-use these expensive shipping containers,

\* At this time the Salesmen's Association, though it has always eschewed price fixing, took an active part in projects beyond its social activities. It cooperated in the effort to establish a uniform sales contract. At a critical period it played a very important part in the development of the Chemical Exposition; it studied the returnable container problem; it gave a course in chemistry under Prof. Frederick E. Breithut of C. C. N. Y., especially designed for its members' needs.

† Invited to this meeting were E. M. Allen, Robt. T. Baldwin, H. G. Carrell, H. L. Derby, Geo. M. Eno, H. S. Farleigh, C. Warren Force, Wm. S. Gray, Albert W. Hawkes, Williams Haynes, Myron S. Hazen, Elon H. Hooker, A. C. Kalbfleisch, August Klipstein, Schuyler L. Parsons, Chas. Reed, Philip Schleussner, Richard Sheldrick, Wm. B. Thom, B. R. Tunison, Jos. Turner, Wm. L. Voight, Edward van Berlo, Eli Winkler, and Jos. Wrench.

which in some cases cost more than their contents, so it became the custom to charge the customer for them when delivered full and to credit the same sum upon their prompt return empty and in good re-usable condition. The practice was carried over to this country and was extended when the steel drum and later the cylinder for compressed gases were introduced. The system lent itself to obvious abuses which became so flagrant that in 1923 the Salesmen's Association appointed a committee, headed by Robert J. Quinn of the Mathieson Alkali Works, consisting of Theodore Sill of Klipstein, B. R. Tunison of "U.S.I.," James Keating of General Chemical, A. M. Hopper of Mallinckrodt, and C. Oscar Lind of *Drug & Chemical Markets*, to investigate and report.<sup>16</sup>

Except for the wholesome effect of calling attention to the evils of non-returns and their consequences, little was actually accomplished until several years later, when standards of safety practice in handling dangerous materials were drawn up by several technical committees of the Manufacturing Chemists' Association, under Morris F. Crass.\* These safety manuals were widely distributed, and this educational program, through its cooperative effort, created favorable reactions from which both producers and consumers have benefited. As an indirect result, stresses due to the enforcement of the charge and credit for the prompt return of multi-trip packages have been considerably relieved.<sup>17</sup>

Akin to the price cutting in the less-than-carload markets, the savage price war fought in the retail drug trade between chain stores and the independents had repercussions in the fine chemical and pharmaceutical industries. Here, too, standardized, widely used, well-known products were used as bait—"leaders" was the popular euphemism of the day—and as the practice spread throughout almost all retail fields, the maintenance of retail prices became a national commercial issue.<sup>18</sup> Colgate & Company was made the defendant in a famous test case by the Government,<sup>19</sup> and the firm's attorney, Mason Trowbridge, served on a special committee † of the National Wholesale Druggists' Association which drafted one of many retail price control laws that were introduced into Congress.<sup>20</sup> Both the U. S. Chamber of Commerce<sup>21</sup> and the Federal Trade Commission<sup>22</sup> diligently investigated the pros and cons, but though the courts stood generally opposed to price maintenance as restricting the free play of competition, nevertheless the issue continued to be fought throughout the period.‡

The sharpness of competition had, nevertheless, some beneficent ef-

\* The outstanding packaging authority of his day, Crass, rose with Grasselli from clerk (1893), to plant supt. (1910), to asst. div. mgr. of operations (1913), to mgr. of package control (1930). In 1936, after Grasselli amalgamated with du Pont, he was brought to Wilmington as packaging specialist, till his retirement in 1943.

† Other members were Robt. R. Ellis, C. Mahlon Kline, and Wm. L. Crounse.

‡ For details, see Chap. 17.



fects. It encouraged many companies to take selling into their own hands and to enlarge their sales staffs. In an effort to relieve the pressure upon prices as much as possible, technical services were developed and more and more chemically trained salesmen were employed. Chemical advertising also improved. Heretofore the typical advertisement of a chemical company had been a "calling card," a mere announcement of its products with its name and address. Now, however, deliberate efforts began to be made to sell either the institution or some of its products. For example, U. S. Industrial Alcohol, Calco, Electro Bleaching Gas, and others began using pictures of their plants; Mathieson Alkali announced a new method of preparing bleach liquor from liquid chlorine devised by its own technical staff; Dow showed photographs of its library and laboratories, emphasizing the company's research. In 1924 Roessler & Hasslacher, inspired by Carl Hazard, its advertising agent, blazed an entirely new path with a bold series of full-page advertisements headed "Confidence," illustrated with pictures of a steeplejack, a lion tamer, an operating surgeon, and the like. This was followed the next year by a "Headquarters" series, showing the buildings occupied by the staffs of famous generals.

The pressure of competition exerted also an outward force and the chemical industry began expanding southward and westward. It was but tracing its historic pattern, following the consuming industries into new territories. At the 1927 meeting of the National Association of Manufacturers at Chattanooga, Elon Hooker prophesied the shift of the manufacturing center of the country from the Atlantic seaboard to the Mississippi Valley, a migration which the chemical industry had already clearly recognized.<sup>23</sup> Growth on the Pacific Coast was similar. As O. W. Tuckwood of the American Potash & Chemical Corporation pointed out in the *Wall Street Journal*,<sup>24</sup> many chemical companies which had started with a single product had added many related chemicals. The Pacific Coast region was, at the time, producing practically all of the natural sodium compounds and potash in the country. The increase in the fertilizer business of California, approximately 15 per cent each year, was very impressive.

The West Coast region began attracting Eastern chemical firms and the C. P. Hall Company of Akron, Ohio, established a subsidiary in Los Angeles,<sup>25</sup> while the Chemical & Pigment Company \* of St. Helena, Maryland, opened a lithopone plant in Oakland.<sup>26</sup> In 1924 a chemical enterprise was established in Los Angeles, the A. R. Maas Chemical Company, destined to become famous as an astute chemical producer and seller which successfully disobeyed many established Eastern tech-

\* Now a division of the Glidden Co.

nical and commercial conventions.<sup>27</sup> The pioneering firms of the section all bestirred themselves, and in 1927 the chemical business of the old trading house of Meyer, Wilson & Company, San Francisco, was split and became Wilson & Geo. Meyer Company.<sup>28</sup> The Stauffer Chemical Company spent \$200,000 in reconstructing its plant at Stege,<sup>29</sup> and the most important development of the time, the Stauffer and Peiser interests, gathered their several joint ventures together into the Consolidated Chemical Industries, incorporated by them for \$2,000,000 in 1927.<sup>30</sup> The new corporation owned outright the old Pacific Bone Coal & Fertilizing Company, organized in 1878, the Texas Chemical Company which since 1916 had been producing sulfuric acid at Houston, and the Louisiana Chemical Company, a similar enterprise started in 1925 at Baton Rouge. In 1929 Consolidated was reorganized and Solomon Peiser and his associates took over the stockholdings of John Stauffer, Christian de Guigne, and the latter's family.

The trend southward had a different inspiration: cheap, abundant raw materials. The Solvay air-nitrogen plant in Hopewell, Virginia; the Eastman wood chemical-cellulose plant at Kingsport, Tennessee; the new rayon plants in Virginia, Tennessee, and North Carolina; the astonishing chemical developments in the Kanawha Valley of West Virginia—all were impressive evidence, and that loyal Southern chemist, Dr. Charles H. Herty, proudly itemized<sup>31</sup> the products, "nitrogen fixation, rayon, paper, caustic soda, chlorine, refractories, glass, products from natural gas, barium compounds, synthetic organic chemical compounds—and most of these . . . manufactured from cheap raw materials."

## REFERENCES

1. Kreps, *Economics of the Sulfuric Acid Industry*, p. 32.
2. Ungewitter, *The Chemical Industry*, League of Nations, C.E.I., Pub. No. 10, p. 12; O. Wilson, *Ind. Eng. Chem.* 24, 388 (1932); W. A. Dyes, *ibid.*, *News Ed.* 9, 22 (1931).
3. Kreps, *op. cit.*, p. 45; Ungewitter, *op. cit.* p. 23.
4. *Am. Druggist* 74, 41 (Dec. 1926); see also J. W. Furness, L. M. Jones, and F. H. Blumenthal, Bur. For. Dom. Com., *Trade Prom. Ser. No. 76* (1929).
5. *Chem. Mkts.* 21, 855 (1927); see also Bur. For. Dom. Com., *Trade Prom. Ser. No. 78* (1929).
6. Clark, *History of Manufactures in the United States*, III, pp. 341-45, 349.
7. *Chem. Mkts.* 28, 364, 448 (1931); Wilson, *op. cit.*
8. Garrett, *A Time Is Born*, p. 127.
9. *Drug Chem. Mkts.* 14, 321 (1924).
10. *Ibid.* 18, 1073 (1926).
11. *Ibid.* 16, 412 (1925); Fed. Trade Comm., *Decisions*, VIII, 535 (1927).
12. *Drug Chem. Mkts.* 12, 848 (1923); see also the final report of the Committee, *ibid.* 1609, and Appendix VII.
13. *Drug Chem. Mkts.* 10, 71 (1922).
14. *Ibid.* 1415; O.P.D. *Reptr.* 47 (June 26, 1922).
15. *Drug Chem. Mkts.* 17, 1480, 1633 (1925); O.P.D. *Reptr.* 65 (June 1, 1925).
16. *Drug Chem. Mkts.* 12, 787 (1923).
17. M. F. Crass, to author, Jan. 25, 1946.
18. C. T. Murchison, *Drug Chem. Mkts.* 10, 393 (1922).
19. *Ibid.* 16, 665 (1925).
20. *Ibid.* 17, 299 (1925).

21. *Am. Druggist* 74, 29 (Feb. 1926).
22. *Drug. Circ.* 71, 890 (1927).
23. *Chem. Mkts.* 21, 604 (1927).
24. Quoted, *ibid.* 25, 150 (1929).
25. Co. memo to author.
26. *Chem. Mkts.* 20, 629 (1927).
27. F. C. Bowman, *Chem. Met. Eng.* 41, 72 (1934).
28. *Chem. Mkts.* 20, 828 (1927).
29. *Drug Chem. Mkts.* 17, 1393 (1925).
30. *Chem. Mkts.* 21, 546, 574, 645, 859 (1927); *Moody's Manual of Investments, Industrials*, 1944, p. 1315.
31. *Chem. Mkts.* 23, 464 (1928).

## *Chapter 3*

### AMERICAN CHEMICAL MERGERS

CAUSES OF WORLD-WIDE CHEMICAL CONSOLIDATIONS DURING TWENTIES; DIVERSIFICATION CHIEF AMERICAN AIM—DU PONT BUYS GRASSELLI—ALLIED CONCENTRATES ON PRODUCERS' CHEMICALS, UNION CARBIDE ON CONSUMERS'—MONSANTO STRENGTHENS HEAVY CHEMICAL LINE THROUGH MERRIMAC—AMERICAN CYANAMID BUYS CALCO AND KLIPSTEIN, ACHIEVING 4TH PLACE IN INDUSTRY—OVER 500 CHEMICAL MERGERS IN U. S.

**W**ORLD WAR I expanded and disrupted the chemical industry in every country. Its demands required increased supplies of toluene, ammonia, chlorine, of sulfuric and nitric acids, of alcohol and acetone, of standard medicinals, all far beyond peacetime requirements. This forced-draft production upset the nicely adjusted equilibrium of raw materials, products, and by-products. By blocking normal channels of international trade, the conflict further increased this unbalance. The natural monopolies in Chilean nitrate and Japanese camphor were broken. New coal-tar chemical industries were created in the United States and Great Britain, while Germany established new chemical projects in synthetic ammonia and nitric acid. We switched from pyrites to brimstone as the raw material for sulfuric acid manufacture. German acid makers cut off from both Spanish pyrites and Sicilian sulfur, had been forced to adopt gypsum. Scores of similar compulsory adaptations to war conditions took place in every country. They touched every group of chemicals.

In the postwar reconversion chemical manufacturers the world over wrestled with maladjustment and oversupply. The universal, distinctive characteristic of this period was severe competition, and since like causes produce like results, the industry in every important chemical-producing country went through a similar phase of evolution.

These were the years of the great chemical consolidations. Neither here nor abroad was competitive pressure always the impelling motive behind these amalgamations. But the intensity of competition throughout the chemical world certainly created an atmosphere encouraging to this movement. The advantages of a united front in foreign trade appealed strongly to British and German chemical leaders, for they depended upon exports to absorb more than half of their outputs. In the United States, where the anti-trust laws forbade direct competitors to combine, the interrelationship of chemical operations naturally sug-

gested to chemical executives the desirability of broadening their company's base by acquiring new lines. Thus, while the immediate motives differed from country to country, and even more so from company to company, the means sought were essentially defense mechanisms in a period of extreme stress.

Large-scale, continuous operation; extensive, organized research; the costly development of new products, had become prerequisites to technical progress and financial success. Since these conditions presuppose big companies and reasonably stable markets, consolidations evolved, fitted to the peculiar structure of this industry and adjusted to divergent national economic and legal backgrounds. The ways and means of accomplishing these ends in the different countries are worthy of particular attention, especially so since growth in size of the business unit is a salient feature of chemical economic development during the Booming Twenties.

Rigidly restricted by the anti-trust laws and liable at any time to be investigated by the Federal Trade Commission, American industries were unable to combine in the cartels and trusts typical of the movement in Europe. Thus in this country the legal framework of the merger movement was quite different than abroad, and the atmosphere, too, was unique. The methods of consolidation were distinctively American. In time they developed some characteristic American motives. These native peculiarities were conspicuously evident in the chemical field. The prominence of individually owned companies; the close economic and technical interrelationships between raw materials, finished products, and by-products; the penetrating influence of technology, all etched these American distinctions more deeply upon chemical mergers than upon the consolidations in the more mature fabricating industries.

The American people, for all their fondness for grandiose size and admiration of sweeping accomplishments, have long evidenced suspicion, even fear, of big business enterprises for the very reason that they are strong and successful. We alone among the important industrial nations have for years bitterly opposed the concentration of control in our industries. We have religiously thwarted one of the most logical, advantageous developments in the modern industrial economy. Paradoxically, our American factories are the world's models for large-scale efficiency and the American people have most richly enjoyed the benefits of mass production. The very elements in our national life which have made these industrial triumphs possible—the wealth of our domestic markets, the physical extent of the country, the ready availability of capital, the venturesome spirit of American businessmen—all create

powerful forces to strengthen the natural antimonopolistic influences.\* The incompatibility of popular megaphonia and official distrust of large corporations with individual ambition and the technical and economic advantages of large-scale operations, have stamped the American chemical industry with a form and spirit quite unlike those of the chemical enterprises of any other country.

At no period did consolidations in the chemical industry conform strictly to the contemporary American pattern. In the heyday of trust-building during the Gay Nineties, no financial genius ever dreamed of a chemical combine. Before the First World War, excepting the American Agricultural Chemical and the Virginia-Carolina Chemical Companies in the closely allied fertilizer field, there were but two important chemical consolidations. Both of these—the General Chemical Company,<sup>1</sup> 1899, and the Mutual Chemical Company,<sup>2</sup> 1906—were strictly private, almost exclusively family transactions. In each case, the values having been determined by mutual appraisal, the new company issued its common stock for the outright purchase of all the tangible assets of its constituents. There was no outside financial underwriting or public sale of stock. It is noteworthy that both consolidations were importantly promoted by technical developments; General Chemical, by the threat of competition from the recently perfected Badische contact sulfuric acid process; Mutual, by the commercial application in this country of the Schultz chrome-tanning process.

By 1920 two important consolidations, the Allied Chemical & Dye Corporation and the Union Carbide and Carbon Corporation, had been completed.† The former amalgamated five and the latter, three companies. All these companies were distinct in their operations and products, but each one in both mergers was closely correlated from the technical and commercial points of view. The war period also saw the expansion of du Pont into heavy chemicals and paint pigments by the purchase of Harrison Brothers, into plastics by the purchase of the Arlington Company; and the establishment of new departments producing coal-tar chemicals and rayon. At the same time, Monsanto had branched out into heavy chemicals by the purchase of the Commercial Acid Company. However, most of the expansion in natural response to unprecedented war demands was met by many new producers and by established companies which enlarged existing plants and added new items.

\* For the affirmative side of the monopoly discussion, see Frederick, *Modern Industrial Consolidation*; Boucke, *Laissez Faire and After*; Snyder, *Capitalism the Creator*; Gras, *Business and Capitalism*; also J. Klein, *Drug Chem. Mkts.* 19, 98 (1926); M. W. Watkins, *Am. Econ. Rev.* 32, Pt. 2, 89 (June 1942).

† For details on Allied, see Vol. III, p. 426; Union Carbide, Vol. III, p. 166.

In this way the war, though it fostered few consolidations, paved the way for the merger movement of the twenties. It strengthened the older, experienced companies and diversified their products. The end of hostilities found them with inflated capacities threatening overproduction, which was dangerous, but they had invaluable assets in up-to-date equipment; in technical and operating staffs trained and tested by fiery experience; and best of all, in fresh chemical ideas.

Even without an anti-trust law, it is unlikely that, at this time, the half-dozen largest companies could have been persuaded to consolidate. Had they done so, there would have been left outside a score of vigorous, efficient independents, perfectly capable of pricking any pretenses of monopoly. The growth of many companies and the extent of our domestic market made it impractical to build anything approaching a chemical monopoly in the United States and infinitely more difficult to maintain such a position than in the European countries. The time had passed when a single, all-embracing American chemical trust could be gathered together. Prior to the war the older chemical leaders, generally men who headed their own companies, might have found in merger a safe and pleasant way to retirement. But the war had not only enlarged and vivified operations, it had also brought to the fore a new generation of executives. These younger men had no intention of melting down their companies in any amalgamation. Their thoughts turned, not to consolidation, but to expansion. The times conspired to promote these policies.

Both as substitutes and for formerly unknown uses, the war had introduced many new chemicals. Innumerable products formerly imported—coal-tar dyes, aromatics, and medicinals, and many others from alkaloids to inorganic salts of the less common metals—were now being made in American chemical plants. Many hitherto untried processes were operating profitably. Equipment of strange types had become common. Diversification had been thrust upon the industry and its advantages proved.

Moreover, the chemical map was dotted with small companies that had prospered during the war, but stood little chance of continuing successfully under peacetime conditions. They presented the older, larger companies with the opportunity to expand by purchase, thereby acquiring products, apparatus, and trained personnel. The close of hostilities created other opportunities for expansion by throwing on the market surplus stocks of raw materials and a wide variety of chemical equipment. The release of thousands of chemists and chemical engineers from the Army, especially from the Chemical Warfare Service, and from munitions plants, relieved what had been a most serious shortage during the war years.

The stage was set and the principal actors cued for their parts in a dramatic period of expansion. Almost with the signing of the Armistice, absorption of smaller, war-born plants began and increased during the short, sharp depression of 1920-21. The merger movement was later accelerated by the public financing of some of the privately owned companies and by the sale of stock and bond issues to provide funds for consolidations. By the time the financial crash came in 1929, most of the important chemical companies had become public stock corporations, their shares traded in on the recognized exchanges.\*

Even at the height of the epidemic of Wall Street speculation during the late twenties, chemical companies escaped the contagion of dangerously free and easy financing. Underlying the whole merger movement in this industry was a resilient chemical philosophy. Almost without exception the mergers, big and little, were based on the principle of diversification buttressed by chemical logic. Legal restrictions kept all producers of fine chemicals or alkalies or dyes from uniting into a single trust. But technological restrictions curbed a swing to the opposite extreme of gathering together a heterogeneous group of nonrelated chemical enterprises. These restraints were doubly helpful. The first headed plans for expansion toward new lines; the second limited these lines rather strictly. If the trust was legally impossible, the "soup-to-nuts corporation" was chemically impractical. These limitations helped leaders of the industry to maintain a strictly chemical point of view, warding off the temptation, strong at that time, to succumb to illusions of overproduction or the blandishments of overfinancing.

In seeking diversification, chemical mergers again diverged from the customary American pattern. They were horizontal consolidations, but not in the meaning which economists attach to this term. They were horizontal, not in embracing similar competing enterprises, but in that their operations remained at the same industrial level. There were exceptions, but in the main chemical companies continued to produce chemicals either as raw materials or as processing tools for other industries. In other words, diversification in a chemical amalgamation did not imply, as it commonly did in other industries, reaching downward to grasp control of raw materials nor upward to gather in consumer goods' markets. Vertical extensions, especially in the direction of the ultimate consumer, have come since, but the chemical logic that governed the mergers of the twenties was simple and direct. It adhered to

\* During this period securities of Dow, Monsanto, Pennsylvania Salt, Mathieson Alkali, Westvaco, Merrimac, Hercules Powder, were listed on various stock exchanges. Among the companies exceptional as remaining closely held corporations were Michigan Alkali, Diamond Alkali, Hooker Electrochemical, Mallinckrodt, Pfizer, Victor, and Mutual.



rigid Aristotelian principles that gave it tremendous weight and peculiar means which must be comprehended if the growth and the policies of the larger American chemical companies are to be understood.

The same lines of chemical reasoning that prompted E. I. du Pont de Nemours & Company to fill its own needs for nitric and sulfuric acids by purchasing Harrison Brothers and to capitalize its experience, equipment, and personnel acquired in explosives manufacture by branching out into coal-tar dyes and cellulose products, continued to guide its expansion during the postwar decade.<sup>3</sup> The company had come out of the war in a powerful position. Its gross sales in 1918 were ten times greater than prewar. Even more impressive, as showing its successful and skillful chemical adaption to peacetime requirements, the company's profits in 1929 were \$78,000,000, only \$4,000,000 less than in 1918.<sup>4</sup> The nitrocellulose lacquer, trade-named Duco, the first signal accomplishment of du Pont research; the successful establishment of the Claude synthetic ammonia process at Belle, West Virginia; and the joint effort with General Motors, Standard Oil of New Jersey, and Dow that led to tetraethyl lead, were the outstanding, internal du Pont accomplishments of the twenties. But during this period the company also pursued a consistent program of external expansion.\*

A substantial block of General Motors Corporation stock was bought and 14,000 shares of United States Steel common, in 1927. The Federal Trade Commission, which questioned 270 corporations as to their investments in the stocks of other companies, ordered a special investigation, July 29, 1927, to determine the "probable economic consequences of such a community of interest." General Motors was obviously a large customer of du Pont and of United States Steel, while the connection of J. P. Morgan with both the automobile and the steel companies was well known. All the companies cooperated by furnishing full information, but only du Pont was asked and "freely and promptly granted" access to the corporation's records. The Commission report was finally made public February 1, 1929, and it not only cleared the companies involved, but had attached to it a minority report by Commissioner Humphrey protesting against the whole investigation as a useless waste of time and money besides being of questionable legality since no violation of the anti-trust laws had been alleged.<sup>5</sup>

The outstanding du Pont merger during these years was with the Grasselli Chemical Company in 1928.† The Grasselli dyes business

\* For du Pont stockholdings of \$500,000 and over, in 1927, see Appendix VIII.

† June 27, 1928, Grasselli stockholders authorized the exchange of one share of \$100 common for three shares of no-par common and the public sale of 100,000 shares of the new issue at \$47. In a circular issued by the National City Co., T. S. Grasselli, pres., was authority for the statement that in 25 plants the company made 60 products with a total tonnage of 1,173,360 (1927).

had been sold three years before to the General Dyestuff Corporation. The Grasselli Powder Company was amalgamated with the du Pont Explosives Department, but the important heavy chemical business was set up as a subsidiary under the old Grasselli name. The du Pont heavy chemical operations, centered at the Harrison plant in Philadelphia and the newer one in Newark, were combined with it under the active management of the experienced, successful Grasselli staff. By this consolidation the du Pont Company not only assured itself a firsthand supply of all basic inorganic chemicals, but it assumed an important position in the heavy chemical market. More than this, the consolidation greatly increased du Pont's interest in paints and pigments. Grasselli was an important producer of zinc oxide and lithopone, thus rounding out the lead pigments acquired with Harrison Brothers.<sup>6</sup> This interest was further increased the following year by the purchase of the Krebs Pigment & Chemical Company, whose specialty had been lithopone sold under the trade name of Ponolith.<sup>7</sup>

Du Pont's old-standing interest in nitrogen underwent important revisions after the Claude synthetic ammonia plant came into production at Belle, West Virginia. Under the subsidiary, Lazote, Inc., this plant started building May 1925 and was in operation the following April.<sup>8</sup> In 1926, with the synthetic ammonia plant in smooth operation, the nitrate mines in Chile were sold.<sup>9</sup> Du Pont in the meantime had bought a controlling interest in the National Ammonia Company, and the du Pont National Ammonia Company was organized with a capitalization of \$13,100,000. J. B. D. Edge was chairman; Jasper E. Crane,\* president, and Dr. Walter Dannenbaum, vice-president and active manager.<sup>10</sup>

During this period the E. I. du Pont de Nemours & Company began to tighten up its corporate structure. In 1928 it took over the minority stock interest of its associates in the du Pont National Ammonia Company, at the same time buying the holdings of the same group in Lazote, Inc.<sup>11</sup> Having acquired American rights to the Casale process, it issued additional stock in 1929 to acquire complete control from its French associates in the Claude process.<sup>12</sup> Minority French interests in the du Pont Rayon Company and the du Pont Cellophane Company were also taken over and thereafter the two companies operated as wholly owned subsidiaries.<sup>13</sup>

While assuming complete American control over these foreign processes, the company was at the same time acquiring an interest in nu-

\* Son of Edward Nichols Crane of the Arlington Co., Jasper Crane joined du Pont upon the merger of these companies in 1915. He was for several years the du Pont representative in Europe and became vice-pres. and member of the exec. comm. in 1929. He was born in Newark, N. J., May 17, 1881, educated at Princeton (A.B., 1901; M.S., 1904) and did special work at Mass. Inst. Tech., 1903-4. He is dir. of Canadian Industries, Ltd., and D. Van Nostrand Co., and alumni trustee of Princeton.

merous foreign chemical enterprises. In England it had a fifty-fifty share with Nobel Industries, Ltd., in a Duco plant.<sup>14</sup> Another Duco plant was opened in France under the managership of William Higgins and in Germany stock of Oberkoks Chemical Company was taken in return for the lacquer patent rights.<sup>15</sup> Through minority stockholdings in the British Nobel and in the German Köln-Rottweil and Dynamit A.-G., the du Pont Company became a shareholder in Imperial Chemical Industries and in I.G. Farbenindustrie.\* In this country, \$25,000,000 was invested in General Motors in 1918 and in 1920 an additional \$33,750,000 was put into common shares, a third of which were later sold to active executives of General Motors to give them a participating interest in the business.† General Motors was then the largest customer for both Duco and Fabrikoid, and the investment which has been very profitable, was most interesting from the chemical point as it led du Pont into the manufacture of tetraethyl lead.<sup>16</sup> Surplus funds were also used to purchase stock of United States Steel,<sup>17</sup> and proceeds from 114,000 shares of the latter sold in June 1928 were used for internal expansion.

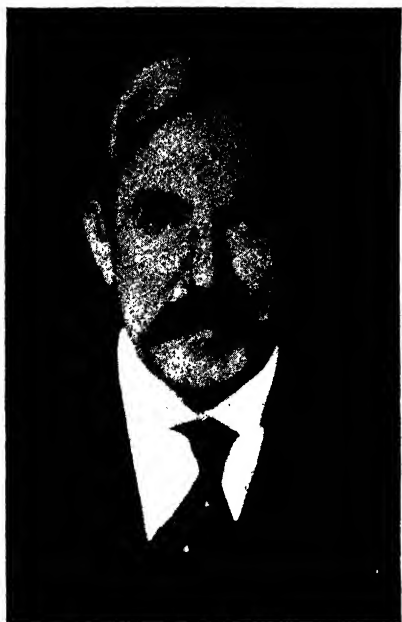
During this period the Lacquer, Rayon, and Dyes Departments were repeatedly enlarged. By 1929 du Pont was the largest maker of coal-tar colors in this country. Except for the sale of 101,575 additional debenture shares in March 1928,<sup>18</sup> all these expansions and diversifications were carried on without outside financing.‡ By 1929 the chemicalization of the company initiated by Pierre S. du Pont had carried it into every branch of the industry except alkalies, fertilizers, and pharmaceuticals.<sup>19</sup>

Since 1919, seven new, separate fields of chemical manufacturing had been entered: 1920, viscose rayon yarn; 1923, Cellophane film; 1924, synthetic ammonia; 1924, photographic film; 1925, industrial alcohol; 1928, seed disinfectants and acetate rayon yarn.<sup>20</sup> Save for alcohol, all these chemical fields were then comparatively new: with the exception of seed disinfectants, all stemmed naturally from the chemical basis of the old explosives business. Three basic policies guided this expansion: (1) du Pont-trained men invariably accompanied the investment of du Pont dollars by additions to the personnel of each business ac-

\* The original investment of \$1,785,522 made in 1925 in these two German explosives firms was transferred into I.G. stock when they were subsequently absorbed by the Dye Trust. This was the only stock of I.G. ever held by du Pont and it was all sold (at a loss) before 1940. [See *Chem. Eng. News* 23, 2222 (1945).]

† The du Pont holdings were roughly a 30% interest in G.M. and after W. C. Durant resigned as pres. in 1920, Pierre S. du Pont succeeded him. In 1927 the following men were dir. of both corporations: Pierre S., Irénée, Lammot, and Henry F. du Pont, John J. Raskob, W. S. Carpenter, Jr., Donaldson Brown, and Alfred P. Sloan, Jr.

‡ "This, I believe, is true with respect to the period mentioned, but there was an issue of bonds before that, which was for the purpose of financing the purchase of General Motors common stock." (L. du Pont, to author, Feb. 5, 1946.)



JOHN STAUFFER



CHRISTIAN DE GUIGNE



A. O. JAEGER



HARRY L. DERBY



*Oil, Paint & Drug Reporter*

**LAMMOT DU PONT**



**JAMES B. D. EDGE**



*Chemical & Metallurgical Engineering*

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*Oil Paint & Drug Reporter*

**EDGAR M. QUEENY**

quired; (2) usually the investment was sufficient to assure ownership, or at least control; (3) such investments were consistently followed by the venture of more capital.<sup>21</sup> Under the presidencies of the three brothers, Pierre S., 1915-1919; Irénée, 1919-1926, and Lammot, 1926-40, these policies were scrupulously followed, and the internal organization began to build about the important executive and finance committees, the actual directing heads in matters of policy and money.

During this decade the two other large explosives manufacturers also progressed far along the road to chemicalization. After its purchase of Celluloid Zapon lacquers and coated fabrics in 1917, the Atlas Powder Company expanded in explosives by merger of the Potts Powder Company, the Giant Powder Company, and others, but it also grew chemically from within by developing products of its own research.<sup>22</sup> At the Stamford, Connecticut, plant, and by acquisition of Brevolite Lacquer Company, North Chicago, and Keratol Company, Newark, it stepped up production of synthetic finishes and artificial leathers and these products were markedly improved. In 1925, with the consulting cooperation of Dr. H. Jermain Creighton,\* experiments on the electrolytic reduction of various sugars to mannitol ( $C_6H_{14}O_6$ ) were resumed. The immediate objective was a process for the economical production of nitromannitol, which seemed a likely detonator of dynamite for industrial uses. By one of those sharp turns in the path of chemical research which so frequently lead to unexpected ends, this work reached the commercial introduction of two new polyhydric alcohols, sorbitol and mannitol, bringing Atlas into entirely fresh chemical fields.<sup>23</sup>

The Hercules Powder Company not only expanded greatly internally, but it also grew by merger.<sup>24</sup> By purchase of Aetna Explosives in 1921, it increased its dynamite facilities approximately a half and its black powder, a quarter. In 1925 it acquired a 50 per cent interest in the Compañía Mexicana de Explosivos, S.A.† That same year it built a new explosives plant on the outskirts of Birmingham, Alabama, and in 1929 two plants to produce nitric acid by the oxidation of ammonia at Parlin, New Jersey, and Bessemer, Alabama. In its new activities—wood naval

\* The original research was undertaken to find a war substitute for scarce, high-priced glycerin by preparing mannitol from mannose obtained from ivory nut scrap from the button makers. It was called off at the Armistice, but not before Creighton had demonstrated the practicality of reducing sugars to alcohols by electrolysis, a discovery that won him the Longstreth medal in 1918. This distinguished electrochemist was born in Nova Scotia, Mar. 2, 1886, trained at Dalhousie U. (A.B., 1906; M.A., 1907) where he returned to teach after postgraduate work at Birmingham (M.S., 1909), Heidelberg, and Zurich (D.Sc., 1911). He came to Swarthmore in 1912 and since 1928 has been prof. chem. He won the Potts medal, 1939, and the Modern Pioneer award of the Nat. Assoc. Mfrs., 1940. He has been pres., Electrochem. Soc.; chmn., Phila. Sect., Am. Chem. Soc.; and is active in the Franklin Inst. and Nova Scotia Inst.

† Sold in 1942.

stores and cellulose products—Hercules acquired the balance of the capital stock of the Yaryan Rosin & Turpentine Company in 1920, dissolved the corporation in 1923, and absorbed it as its Naval Stores Department which now operates the plants at Brunswick, Georgia, and Hattiesburg, Mississippi. In 1926 Hercules merged the Virginia Cellulose Company by outright purchase, establishing it as the Virginia Cellulose Department.<sup>25</sup> This company had been organized three years previous to take advantage of the opportunity offered by the sale of a government nitrating plant at Hopewell, Virginia, adjacent to a surplus stock of cotton linters, for turning out processed nitrocellulose for the new synthetic fibers and lacquer industries.<sup>26</sup>

The two great chemical consolidations of the World War I period—Allied and Union Carbide—pursued almost directly opposite policies of expansion during the first postwar decade. Within the entire Allied Chemical & Dye group there was but a single merger: the entrance of National Aniline into the medicinal field by purchase in 1922 of Heyl Laboratories.<sup>27</sup> Union Carbide and Carbon, on the other hand, extended and strengthened almost every part of its business by a number of mergers. Yet the most important chemical developments in both companies during this decade—Allied's air-nitrogen plant at Hopewell and the amazing commercialization of the new line of aliphatic compounds by Carbide and Carbon Chemicals—were both internal developments, the results of these companies' own researches, financed by their own venture capital.

In this period, too, Allied under Orlando Weber adopted its firmly fixed, almost unique policy of confining its activities strictly to the production of producers' goods, chemicals consumed as raw materials by other manufacturing industries.<sup>28</sup> The commercial reasoning is self-evident: in this way Allied avoids any semblance of competition with its own customers.\* Union Carbide, on the contrary, extended its elec-

\* The good will accrued in this manner is somewhat intangible, but it has become increasingly more valuable as other chemical companies have extended their lines in plastics, fibers, coatings, insecticides, and innumerable branded chemical specialties for the industrial, agricultural, automotive, and household trades. Like many of Orlando Weber's vigorously pursued policies, this has been warmly debated. Though hiding from personal publicity, he managed to draw the spotlight of interest and controversy. For sheer mental ability he had few peers among the executives of the industry; a serious student of economic theory, a consummate interpreter of statistics and financial statements, a shrewd analyst of business trends and political forces. His decisions, founded on his firm convictions, were inexorable, so that as an executive he appeared to his contemporaries to be uncooperative, competitive, and militaristic. Born in Grafton, Wis., Oct. 6, 1878, with a Socialist labor leader for a father, Orlando Weber became a pioneer in Michigan Avenue's (Chicago) "automobile row." Eugene Meyer took him to Washington on the War Finance Corp. and then to N. Y. as pres. of Allied in which Meyer was interested through his financial backing of Beckers Aniline. He became chmn. in 1931, retired in 1935, and died, Sept. 6, 1945.

tric battery business, its welding equipment and supplies, and notably sold ethylene glycol as an anti-freeze under the trade name Prestone, thus becoming a leader in the move towards consumer goods, which was to become so conspicuous a feature of chemical company growth during the thirties.

The Union Carbide acquisitions during this period were numerous and varied. The interest in ferroalloys prompted the purchase, in 1926, of the mine, mill, and reduction plant of the United States Vanadium Company at Rifle, Colorado. Three years later these holdings were extended in the Long Park region by buying certain assets of the Standard Chemical Company \* and the Vanadium Alloys Corporation.<sup>29</sup> These excursions into vanadium † came opportunely. Vanadium catalysts, destined to replace platinum in the contact sulfuric acid and in the Gibbs-Conover phthalic anhydride processes,<sup>30</sup> were introduced in 1926, opening a secondary market for this metal which previously had been used almost exclusively in alloying tough steels. By 1929 these strictly chemical uses had reached a value of \$75,000 to \$100,000 a year,<sup>31</sup> and these properties were a valuable and comforting backlog.

Union Carbide units added to their power facilities at Sault Ste. Marie and a new hydroelectric plant near Hawks' Nest, West Virginia. These power stations were owned respectively by the subsidiaries, Michigan Northern Power and the New Kanawha Power Companies. In 1929 Union Carbide's subsidiary, Aktieselskabet Saudefaldene, added to the three hydroelectric stations in Norway by the purchase of the Aktieselskabet Meraker Smelteverk, with four power plants on the Kopperaen River.<sup>32</sup> Abroad and in this country these additional installations supplied power to the company's electric furnaces for production of carbide and ferroalloys. Purchase of the Acheson Graphite Company in 1928 carried operations into a new but closely allied field. Two years before, the patents and other assets pertaining to the dry-cell battery business of the Manhattan Electric Supply Company and all property of the Corliss Carbon Company had been acquired. Beginning in 1928 with the purchase of the Michigan Ox-hydric Company and the Memphis Oxygen Company, the oxyacetylene business was markedly enlarged by the building or purchase of 27 oxygen and 24 acetylene plants.<sup>33</sup> This pro-

\* In 1911 Standard Chemical was chartered in Del. and in 1929 sold its mining and other lands and mining and power-generating equipment to United States Vanadium Corp. Vanadium Alloys Corp. was chartered in 1928 in Colo. In 1929 it sold all its mining claims, mining equipment, and other personal property there to United States Vanadium.

† The metallic element was identified by Del Rio in 1801; investigated in 1830 by Sefström, and because of its brilliant, multicolored compounds, named by him in honor of Vanadis, the beautiful Scandinavian goddess of youth and love, the Freya of Wagner's *Rheingold*. [See J. Alexander, *J. Soc. Chem. Ind.* 48, 871 (1929).]



gram was paid out of the company's surplus funds until 1929, when a \$53,000,000 common stock issue, the largest chemical financing up to this time, was sold.<sup>34</sup> All this great growth was within the company's distinctive scope: carbide, ferroalloys, carbon, acetylene, the industrial gases, electrodes, batteries and flashlights, and finally the aliphatic chemicals from natural gas and gasoline; all products peculiar to the organization and quite different from those of any other chemical company.<sup>35</sup>

In like manner the Monsanto Chemical Works \* advanced along lines clearly outlined during the wartime growth. The most important acquisition, the purchase of the Merrimac Chemical Company, † oldest and largest manufacturers of industrial chemicals in New England, with gross assets of \$6,700,000 and an income in 1928 of \$470,000,<sup>36</sup> had been forecast by the absorption of the Commercial Acid Company in 1918. Since Merrimac had won and successfully held a distinguished, unique position in its territory, it was discreet to continue the business, paid for in \$4,500,000 worth of Monsanto stock, as a separate division under the old management; Salmon W. Wilder advanced to chairman of the board, Charles Belknap became president, and William M. Rand, vice-president in charge of sales.

Monsanto strengthened its hand in the coal-tar chemical field by acquiring from the Mathieson Alkali Works its Commonwealth Division, makers of benzoates<sup>37</sup> and by taking over the Rubber Service Laboratories Company and its subsidiary, the Elko Chemical Company, through an exchange of stock of \$1,500,000 market value and \$300,000 in cash.<sup>38</sup> The bold experiment of John F. Queeny, when Monsanto purchased a half-interest in the Graesser-Monsanto Chemical Works, Ltd., at Ruabon, North Wales, in 1920, came to an interesting revision in 1928, when his company bought out the Graesser half-interest for \$917,040.<sup>39</sup> This chemical invasion of Britain did not stop here. The English subsidiary, rechristened the Monsanto Chemical Works, Ltd., acquired within that very year three properties: the Wear Tar Works of Brotherton & Company, the British Saccharin Manufacturing Company, and the methyl salicylate business of K. B. Mavlankar.<sup>40</sup> In 1930 the active management of these English properties was placed in the hands of Lloyd F. Nickell, ‡ previously manager of the East St. Louis works.

\* Name changed, 1933, to Monsanto Chemical Co.

† Merrimac, founded 1853, had bought out the Cochrane Chemical Co. in 1917, joining the two largest chemical manufacturers in New England, and in 1924 the Anderson Chemical Co. of Wallington, N. J., moving its production of solvents, nitrocellulose solutions, and lacquers, to its Everett, Mass., plant.

‡ This technically trained executive made the violent transition from plant mgr. in the Middle West to chief executive in England with auspicious success. He was born in Padua, Ill., Feb. 6, 1884, and had all his chemical training at U. Ill. (A.B., 1909; A.M., 1911; Ph.D., 1913). Till 1917 he was asst. prof. chem. at Washington U., St. Louis, when he went with Monsanto.

These expansions in Great Britain captured Queeny's lively industrial imagination. He personally conducted the negotiations and drew plans for the Americanization of the subsidiary which included the addition of many new coal-tar derivatives. To free himself from exacting duties and in line with his determined plan to step out of active executive management, he became chairman in 1928, and his son, Edgar Monsanto Queeny, was elected president.\* Almost immediately the company's vigorous program of expansion was enlarged and vivified. One of the first steps, April 1929, was to double the capitalization and to approve a carefully drawn campaign of chemical development.

The most striking example of the reinforcement of an American chemical enterprise by diversification through merger is furnished by the American Cyanamid Company.<sup>41</sup> In 1910 sales of this company were 100 per cent in the fertilizer field. In 1916 although Ammo-Phos, the concentrated ammonium phosphate plant food, had been added, a tenth of the company sales was non-fertilizer, and by 1926, these had increased to just over half. These outside sales were chiefly of cyanide, used in the extraction of gold from its ores. This business was expanded greatly during World War I and American Cyanamid's share the world over was 80 per cent. During the early twenties the company added liquid hydrocyanic gas, sold for the control of scale insects and for the fumigation of ships, flour mills, warehouses, etc.; calcium cyanide, the insecticide and rodenticide marketed under the trade name Cyanogas; sodium ferrocyanide; guanidine rubber accelerators; and a few other derivatives of hydrocyanic acid. Though less concentrated, the company's operations were still reared upon the single, basic raw material, cyanamide.

Frank S. Washburn,† the founder, died October 9, 1922, and James

\* Edgar Queeny joined Monsanto, Oct. 1919, as its first adv. mgr. He was born Sept. 29, 1897; had been educated at Cornell; and served in World War I as Lt. (j.g.) U.S.N. In 1920 he became secy.; in 1924, vice-pres.; in 1928, pres.; in 1938, chmn. His father, a driving individualist, built the company on a firm foundation through dogged determination and hard labor; the son, a friendly, inspiring, broad-visioned leader erected upon that base by increasing the capitalization; creating a strong, loyal organization; extending the company's activities in many directions. He has been prominent in the Nat. Assoc. Mfrs.; dir., Nat. Ind. Conference Bd., Washington U., National Bearing Metals Corp., American Airlines, the Mercantile-Commerce Bank & Trust Co. A keen sportsman and photographer, he has written several delightful sketches of travel and hunting trips and is the author of *Spirit of Enterprise* (1943), an outspoken expression of the industrialists' view of the economic-political scene in the midst of World War II. (See also *Fortune* 55, Jan. 1939.)

† One of the real hydroelectric pioneers, Frank Sherman Washburn was born at Centralia, Ill., Dec. 8, 1860, and educated as a civil eng. at Cornell (1883). After a varied professional career here and in So. Am., he became interested in Southern power projects. This prompted him to acquire American rights to the Caro-Frank cyanamide process to develop which he organized American Cyanamid in 1907. (See Haynes, *Chemical Pioneers*, p. 243.)

B. Duke, an early backer and important shareholder, on October 10, 1925. Both these men were intensely fertilizer-conscious. Their brilliant vision of the nitrogen-bearing plant-food ingredient, cyanamide, produced close to the greatest fertilizer consuming area of the country, had been tarnished when the politicians began playing with Muscle Shoals, and it was soon to be eclipsed by the synthetic ammonia plants at Belle and Hopewell. The new president, William B. Bell, law-trained Quaker and a superlative industrial strategist, determined to widen the company's activities. The first move was the purchase of the American rights to the British urca-formaldehyde plastic, Beetle. In 1929, three long steps were taken in different directions when Cyanamid took over the Kalbfleisch Corporation, the Calco Chemical Company, and the Selden Company, advancing into the heavy and coal-tar chemicals and catalysts.

In 1929 American Cyanamid revised its financial structure by changing the \$20 par Class A and B common stock to no-par and increasing the Class B shares from 400,000 to 1,600,000, exchanging two of these for one of the 6 per cent cumulative preferred. In the 17th Annual Report covering the year that ended June 30, 1929, W. B. Bell reported that of the additional B shares, 96,930 were issued in exchange for the preferred; 160,838 for the purchase of Calco, Crown, May, and for part of the assets of the Beachville White Lime Company; and 737,979 sold at \$20 to finance plant improvements and extensions costing \$13,524,941.<sup>42</sup>

When in 1920 Franklin H. Kalbfleisch retired as active head of the business his father founded in 1829, he named as his successor Harry Leigh Derby,\* and Derby, scanning the broadened postwar chemical horizons, was himself planning a diversification of this heavy chemical enterprise, when merger with Cyanamid was proposed in exchange for 75,877 shares of that corporation's B stock.<sup>43</sup> Into the consolidation went also two Kalbfleisch subsidiaries, the Kalbfleisch Bauxite Company with mines in Arkansas and Georgia, and the John C. Wiarda & Company, which under the aggressive management of George E. Taylor † carried

\* Energetic, decisive, essentially a sales executive, Harry Derby is the country boy of the good old American tradition—born in Afton (pop. 700) near Birmingham, N. Y., July 3, 1882—who came to town and made good. He had been traffic and sales mgr. of the Casein Mfg. Co. at Bainbridge, N. Y., near his home town, when in 1913 he joined the Kalbfleisch organization of which he became pres. in 1920. When American Cyanamid & Chemical Co. was organized in 1932, he became pres. of this subsidiary, retiring in 1946. He has been a distinguished public servant of the industry, serving as chmn. of the important exec. comm., Mfg. Chem. Assoc., and of the tariff and veterans' reemployment comms., Nat. Assoc. Mfrs.; and on the Nat. Labor Bd. In his younger days he collaborated on the *Traffic Library*, still a standard textbook.

† Taylor, who had been raised in the Wiarda business, was born in Brooklyn, July 12, 1890, and educated at N. Y. U. (A.B., 1913).

on a profitable importing and jobbing business selling a varied line of chemicals of other manufacturers. Following plans laid by Harry Derby, Kalbfleisch was itself promptly enlarged in capacity by purchase of the Superior Chemical Company, Joliet, Illinois, makers of alums, and of the aluminum sulfate plant of the Armour Fertilizer Works at Cincinnati.<sup>44</sup>

Acquisition of the Calco Chemical Company\* carried Cyanamid into an entirely new sector of the industry, and wisely this subsidiary was operated quite independently under Robert C. Jeffcott, with headquarters at the big plant at Bound Brook, New Jersey. Alliance with Cyanamid furnishing additional working capital, Calco forwarded its own plans for growth, and within the next year it merged eight companies operating in different specialized branches of the same general field: the Heller & Merz Company, the Beaver Chemical Corporation, Dye Products & Chemical Company, Garfield Aniline Works, Gaskill Chemical Corporation, Passaic Color Corporation, Wetterwald & Pfister Company, and the Wetterson Dyestuffs Corporation.<sup>45</sup> Having originally specialized in the production of coal-tar intermediates,† these purchases rounded out the Calco line of dyes. The company now stood behind du Pont and National Aniline in third place as the largest domestic producer and it had also an important place in dry colors. Most of these companies were promptly absorbed and their plants dismantled. However, operation of the Beaver plant at Damascus, Virginia, was carried on for several years, and the old, well-known firm of Heller & Merz, in an enviable niche in the field of paper dyes, retained its identity as a sales organization.

The Selden Company engaged in a particular, almost exclusive business. It was successor to the Walker Chemical Company which in 1918, at Pittsburgh, had been pioneer, large-scale manufacturers of phthalic anhydride. Under its director of research, Dr. Alphons Otto Jaeger, it had entered the manufacture of vanadium catalysts, first for the production of its own phthalic and later for the contact sulfuric acid process. Following this path, Cyanamid organized the Catalytic Process Corporation in 1929, consolidating the patent interests in the con-

\* Calco received 88,370 shares of Cyanamid Class B common—2½ for each share of Calco preferred and one for 9 of Calco common and \$46 per share for 32,815 shares of Calco class B common bought by the Amalgamated Phosphate Co. [See *Chem. Mkts.* 24, 177 (1929).]

† The purchase of small coal-tar dyes and medicinal companies continued and during 1929-31 the following were amalgamated by Calco: Crown Chemical Corp.; Essex Aniline Works; Granton Chemical Co.; Kerin Mfg. Co.; King Chemical Co.; A. Klipstein & Co., Dye Dept.; May Chemical Works; National Ultramarine Co.; Textile Chemical Co.; Trico Chemical Co.; Williamsburg Chemical Co. [See *Ind. Eng. Chem., News Ed.* 9, 157 (1931); *Moody's Manual of Investments, Industrials*, 1944, p. 823.]

tact acid, the phthalic anhydride, and other related processes previously held by Calco, Selden, and the parent corporation. This new subsidiary, which licensed the various processes, led naturally to the Chemical Construction Corporation, organized the same year to design and build sulfuric acid and other chemical plants. The next step was the addition of the Chemical Engineering Corporation, controlling synthetic ammonia and methanol processes. These engineering enterprises created a unique phase of Cyanamid's business. The building of chemical plants, chiefly sulfuric acid, synthetic ammonia, and nitric acid operations, on a "turnkey" basis, that is, delivered in running order, soon grew into a profitable, world-wide enterprise.

Within another twelve months Cyanamid augmented its activities by a series of mergers that carried it into the production of biologicals, nitrocellulose products, and explosives.\* It had become the fourth largest American chemical corporation and the one with by far the most ramified activities.

During the Booming Twenties some 500 mergers were completed among chemical companies.† And yet the chemical industry trailed far behind iron and steel, foodstuffs, nonferrous metals, textiles, petroleum, automobiles, even banks, hotels, and department stores.<sup>46</sup> There were sound reasons for this, rooted in economic facts. By 1920 the average size of chemical corporations was already larger than the average of all industry. Furthermore, the demand for chemicals was still expanding. To these economic discouragements to consolidation were added legal and technical obstacles. Despite the extreme complexity of the industry, the mergers of this period were set up within a consistent framework, the blueprint of which is clearly drawn, for both large and small companies, in the typical amalgamations that we have considered. While in the case of certain heavy chemicals purchase of a Middle West plant presented obvious advantages to an Eastern company in saving of freight costs, nevertheless the merger movement of the twenties was fundamentally a realignment of producers undertaken to secure the peculiar technical advantages of diversification in chemical manufacture. It was guided by straight-laced technical considerations. The chief benefits

\* The mergers of Lederle Labs. and Davis & Geck, American Powder Co., and later during 1933-34 of the Burton and two smaller explosives companies, also the alliance with Pittsburgh Plate Glass in the alkali plant at Corpus Christi, Texas, all belong to the period covered by Vol. V.

† An exact figure has never been computed. *Recent Economic Changes* in which a special staff of the Nat. Bur. Econ. Res. collaborated, records from 1919 to 1928 a total of 7,259 mergers in all industries, of which 355 were chemical consolidations. Willard L. Thorp of this staff pointed out in *Chem. Mkts.* 26, 159 (1930), that "the year 1922 saw the lowest number with 376, while 1928 the highest with 1,259," adding, "and 1929 promises to break all previous records." This promise was royally fulfilled, and the estimate of 500 chemical mergers, if rough, seems reasonably correct. (W. H.)

accruing were the economies of larger operations, often undertaken for self-consumption, and only secondarily the commercial advantages of handling a more complete line of chemicals.

## REFERENCES

1. *The General Chemical Company after Twenty Years*, p. 14.
2. W. Haynes, *Chromium Chemicals*, p. 17; *Chem. Met. Eng.* 37, 17 (1930).
3. B. Darlington, *Du Pont Mag.* 28, 1, No. 12 (1934), 29, 1, Nos. 1-2 (1935); Haynes, *Ind. Eng. Chem.* 24, 704 (1932).
4. *Fortune* 80 (Dec. 1934).
5. Fed. Trade Comm., *Report on du Pont Investments*, Feb. 1, 1929.
6. *Chem. Mkts.* 23, 493 (1928); *Ind. Eng. Chem.* 20, 1340 (1928); *Chem. Met. Eng.* 37, 16 (1930).
7. *O.P.D. Repr.* 20 (Apr. 22, 1929).
8. *Ibid.* 48 (June 7, 1926); *Chem. Mkts.* 19, 186 (1926).
9. *Com. Fin. Chron.* 126, 859 (1928); *Wall St. J.*, Mar. 24, 1928.
10. *Com. Fin. Chron.* 124, 785 (1926).
11. *Chem. Mkts.* 22, 421 (1928).
12. *Ibid.* 20, 510 (1927); 25, 69 (1929).
13. *Ibid.* 24, 177 (1929).
14. *Ibid.* 20, 510 (1927).
15. *Ibid.*; *Ibid.* 25, 629 (1929); *O.P.D. Repr.* 20 (Apr. 22, 1929).
16. Fed. Trade Comm., *op. cit.*
17. *Ibid.*; *Wall St. J.*, *op. cit.*
18. *Wall St. J.*, *op. cit.*
19. T. M. Switz, *Chem. Met. Eng.* 37, 11, 16 (1930); Haynes, *Ind. Eng. Chem. op. cit.*
20. Dutton, *Du Pont*, p. 278.
21. *Ibid.* p. 279.
22. Isaac Fogg, to author, Feb. 6, 1946.
23. Haynes, *This Chemical Age*, pp. 252-61.
24. *Chem. Mkts.* 20, 490 (1927); *Moody's Manual of Investments, Industrials, 1944*, p. 1714.
25. *O.P.D. Repr.* 64 (Aug. 2, 1926).
26. *Rayon Synthetic Yarn J.* 14, 32 (June 1933).
27. *Drug Chem. Mkts.* 10, 18 (1922).
28. Switz, *op. cit.*
29. *Chem. Mkts.* 24, 629 (1929); *Moody's Manual, op. cit.* p. 2415.
30. L. F. Nickell, *Chem. Met. Eng.* 35, 153 (1928); E. P. Partridge, *Ind. Eng. Chem.* 21, 40 (1929); Riegel, *Industrial Chemistry*, 2d ed., pp. 30, 408.
31. B. D. Saklatwalla, *Hearings Ways & Means Comm.* (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 7, 1929, p. 33.
32. *Chem. Mkts.* 24, 629 (1929).
33. *Moody's Manual, op. cit.* p. 2287.
34. *Chem. Mkts.* 26, 142 (1930); *Com. Fin. Chron.* 192, 2093 (1929).
35. Switz, *op. cit.*
36. S. W. Wilder, *Ind. Eng. Chem.* 23, 848 (1931); *Chem. Mkts.* 25, 513 (1929); Co. memo to author; *Fortune* 88 (Jan. 1939).
37. *Chem. Mkts.* 26, 409 (1930).
38. *Com. Fin. Chron.* 128, 3696 (1929); *Chem. Mkts.* 25, 513 (1939); *Fortune* 86 (Jan. 1939).
39. *Poor's Manual of Industrials, 1939*, p. 2712; *Drug Mkts.* 21, 563 (1927).
40. *Moody's Manual, op. cit.* p. 2229; *Chem. Met. Eng.* 36, 770 (1929); *Chem. Mkts.* 26, 409 (1930).
41. *After Thirty Years*, American Cyanamid Co. (1928), reviews the growth of this company in detail; see also *Ind. Eng. Chem.* 22, 301 (1930); *Fortune* 66 (Sept. 1940).
42. *Com. Fin. Chron.* 192, 1589 (1929).
43. *Ibid.* 798; Haynes, *Chemical Pioneers*, p. 55.
44. American Cyanamid Co., *Ann. Rept.*, Aug. 1930.
45. *O.P.D. Repr.* 44 (Nov. 17, 1930), 19 (Nov. 24, 1930); *Moody's Manual, op. cit.* p. 823.
46. W. L. Thorp, *Chem. Mkts.* 26, 159 (1930); *O.P.D. Repr.* 110 (Feb. 6, 1930).

## *Chapter 4*

### FOREIGN CARTELS AND TRUSTS

RATIONALIZATION MOVEMENT IN EUROPE—CHEMICAL PRODUCERS BAND IN TRUSTS AND INTERNATIONAL CARTELS—CONTROL OF NATIONAL CHEMICAL PRODUCTION IN GERMANY, ENGLAND, FRANCE, AND ITALY IN HANDS OF I.G., I.C.I., KUHLMANN, AND MONTECATINI—GENEVA ECONOMIC CONFERENCE ATTACKS HIGH TARIFFS, ESPECIALLY AMERICAN, AND EVADES CARTEL QUESTION—INTERNATIONAL CHAMBER OF COMMERCE INEFFECTUAL.

IN EUROPE the wild surge of political and economic forces that swept business enterprises from coal mines to newsstands into consolidations during the postwar years, came quickly to be known as the rationalization movement. This was not a catch phrase. It was coined neither to hide its political implications nor to gloss over its monopolistic objectives. It was, in fact, an honest term describing frankly, if optimistically, a program which most Europeans sincerely believed was to be their economic salvation during the tumultuous period of ultranationalism and currency instability that followed the First World War. It failed to do this, but the rationalization movement did prepare the way, straight and smooth, for the planned economies of the totalitarian governments of the thirties.

It is quite understandable why European chemical manufacturers sought to attain strength and stability by banding together in great nation-wide trusts and then entering into international cartels. Their home markets were so small that, if divided among several warring producers, the competition was certain to be cutthroat and the efficiencies and economies of large-scale production must be sacrificed. Since most of these chemical companies were dependent upon exports, the allocation of foreign markets by cartel agreements to prevent price wars made a particularly strong appeal.

The European governments had good reasons to solidify their chemical industries. All nations were most anxious to achieve chemical self-sufficiency. Most of them—Germany and Austria particularly—desperately needed economic stability, and they were solicitous indeed of every manufacturing enterprise that held forth any promise of providing profitable employment at home and establishing foreign credits. Accordingly they sanctioned, even encouraged, the nationalization of

their chemical production into trusts and cordially approved cartel agreements that promised to make foreign trade more profitable.

For these same reasons the big chemical companies roused widespread enthusiasm among the people. Knowledge that these corporations exercised almost perfect monopolies and that they frequently sold cheaper abroad than to domestic consumers, did not dampen the patriotic pride which they inspired. This was always true in Germany. Under the Kaiser, during the Republic, through the reign of the Nazis, the highly centralized, aggressive German chemical industry remained a popular idol, a proud symbol of the *Herrenvolk*.

In Germany the seeds of modern industrialism were planted late, but they sprouted quickly. Stimulated by the Franco-Prussian War (1870-71), they blossomed luxuriantly. The severe depression which followed taught the youthful German industries the dangers of destructive competition and persuaded them to sink independence in cooperation.<sup>1</sup> The domestic market was limited, yet the advantages of large-scale production were vividly impressed upon the industrialists and the Government. Big business, which of necessity meant export business, soon came to be identified with the place-in-the-sun for Germany which the Kaiser was so effectively popularizing. Individuals or partnerships controlled most German manufacturing enterprises, and cherishing their own integrity, they turned naturally to a very old device, the cartel.\*

This badly abused term † has been defined by Robert Liefmann, the outstanding German authority, as "voluntary agreements between, or associations of, independent enterprises of similar type to secure a monopoly of the market."<sup>2</sup> The distinctly voluntary basis of the cartel agreement separates this form of organization sharply from that of the trust. I.G. Farbenindustrie, popularly known in this country as the "German Dye Cartel" or the "German Chemical Cartel," is not a cartel at all, but a trust. It completely controls the policies, the operations, the finances of its constituent companies and subsidiaries. It has entered into numerous cartels, but these are external agreements made with other companies. The trust is obviously more powerful, more closely knit, or as the Germans say, a "higher" type of organization.

In seeking to control the market, members of a cartel agree among

\* It has been noted frequently that trusts are commonly built up in prosperous times while cartels are formed during periods of economic adversity. Weidenhammer observes that "corporate mergers have to be financed either out of retained profits or from flotation of securities. When depression strikes or when drastic economic dislocations, like those created by the end of wars, curtail their market, independent producers huddle together in cartels to seek immunity from the threatened effects of *laissez faire*." [See *Am. Econ. Rev.* 35, 325 (1945).]

† For good discussion of definitions and misuse of this word, see article on cartels by H. W. Ambruster, in *Encycl. Americana*, 1945.



themselves to do or to refrain from doing certain specific acts in the course of their business activities. Their aim is frankly monopolistic. Their power depends upon the extent of the monopoly which they can achieve. But Liefmann is at great pains to point out that they never can consummate complete monopoly. Only God or the Government can effectuate perfect monopoly. The cartels never achieve monopolistic control in the sense of such natural monopolies as Chilean nitrate and German potash or the legal monopolies granted by exclusive franchises, concessions, and patents. Indeed, unless cartel agreements are sanctioned by law so that they become enforceable contracts, the cartel is a very tenuous instrument.<sup>3</sup>

In this country the old "rings" and "gentlemen's agreements" were essentially cartels. They were not sufficiently strong to enforce their own terms, so in the stress of competition the stronger, more compact trusts naturally evolved. Since Theodore Roosevelt's Administration, trusts have been opposed in this country by anti-trust laws and many "trust-busting" campaigns. Abroad, however, the attitude was more friendly. In Germany, so long as business activities were not palpably contrary to public interest, the Government always maintained a hands-off policy in the industrial world. In England, the approach was different, but the result was similar. Since the Magna Charta English courts have been exceedingly loath to interfere with the personal right to make contracts so long as both parties receive definite, tangible benefits and the agreement is not contrary to public interest. English jurists have repeatedly refused to weigh or compare the benefits just so long as the consideration received is mutual, i.e., flows to both parties of a contract, and in England restraint of trade, in the meaning of our anti-trust laws, is not held to be contrary to public interest. In both countries, therefore, voluntary agreements among manufacturers were a practical method of controlling their own market.

In Europe the cartel traces back to the guild, a voluntary association sanctioned by custom and by law. While its form as we know it dates only from the era of large-scale production in Germany, the oldest cartel, the Neckar Salt Union, was organized in 1828.<sup>4</sup> Between 1836 and 1844 there was a cartel among the four Prussian alum works, and similar associations covering salt and bismuth go back to the 1860's. Natural raw materials were the favorite subject of early cartels, and even in Germany it was not until the late 1870's that they entered the field of manufactured goods.\*

\* The outstanding work on the consolidation movement in Germany is Robert Liefmann's *Cartels, Concerns and Trusts* (trans. Prof. D. H. Macgregor of Oxford), a popular, but scholarly book by a life-long student of the subject. See also Brady, *Rationalization Movement in German Industry*; Fraser, *Germany Between Two Wars*;

It was during this heyday of German cartelism that two organizations which later played dramatic parts on the American chemical stage came into existence. As early as 1904 the six leading German dye manufacturers began to gravitate into two groups. Badische, Bayer, and Agfa \* formed a "community of interest" of the cartel type to run for fifty years, by which they divided world markets and exchanged certain basic patents. On the other side, Hoechst purchased 99 per cent of the stock of Kalle and a 75 per cent stock interest in Cassella. These two groups quickly came to an understanding, an informal but rather effective offensive and defensive alliance. The exact terms of this understanding have never been made public, but they undoubtedly governed their activities in the export markets.<sup>5</sup>

In 1916, in the midst of the First World War, this anomalous alliance was replaced by a more binding cartel agreement. This was announced with a boastful flourish, an open declaration of war upon the infant dye industries of Great Britain and the United States. This true German Dye Cartel allocated markets between the two groups. But it went much further than the former alliance in concentrating the manufacture of certain types of dyes in certain factories and in attempting to adjust inequalities thus created by a division of profits. Its formation was so obviously a realignment for vigorous, concerted action and so plainly a challenge to American dye interests, that it served the useful purpose of rousing Congress to the necessity of providing extraordinary tariff protection for this branch of the American chemical industry.<sup>†</sup>

The Potash Cartel had quite a different early history. Like Sicilian sulfur, this natural monopoly appeared on the surface to be a perfect opportunity for the exploitation of the consumer. But it ran into competitive difficulties.<sup>‡</sup> The illusion of monopoly was smashed to bits in 1909, when American fertilizer companies found certain members of the Potash Cartel willing to break the agreement and sell to them at prices 40 per cent below the agreed schedule.<sup>§</sup> To conserve one of Germany's most important natural resources, the Government stepped boldly in and assumed control. The famous Potash Law of 1910—enacted by the Reichstag, May 25—made compulsory the voluntary cartel agreement on prices and production. While the details of administration and selling were left to the Syndicate, nevertheless the Government was em-

Levy, *Industrial Germany*; Michels, *Cartels, Combines and Trusts in Post-War Germany*; Bruck, *Social and Economic History of Germany from William II to Hitler*; Borkin and Welsh, *Germany's Master Plan*.

\* Akt.-Ges. f. Anilin-Fabrikation, Berlin.

† See Vol. III, p. 249.

‡ See Stocking's excellent *Potash Industry*, Chaps. 1-4; for the parallel difficulties of the Sicilian sulfur monopoly, Haynes, *Stone That Burns*, Chaps. 4-5.

§ See Vol. II, p. 141.

powered to fix domestic and foreign prices and prescribe the participation of the various firms in total sales, a virtual throttlehold upon distribution.

In the chemical field, therefore, all three major types of centralized control of the market had developed in Germany by the end of World War I. The dye industry exhibited a voluntary alliance represented by the Badische-Bayer-Agfa Cartel and a closely knit combine or trust, the Hoechst holding company controlled Kalle and Cassella through stock ownership. In the potash industry a state-controlled cartel had been established.

During the postwar period of violently fluctuating prices followed by the great inflation, the German cartels disintegrated because their members found it advantageous to disregard the restrictions placed upon them by the voluntary agreements. Control of the market became impossible. Independence of the market was sought. The cartels were followed by stronger, vertical combinations which sought to establish control from raw material to finished goods.<sup>6</sup>

Almost from the first conference on reparation dyes, the rumor spread that the German chemical companies were planning to consolidate. Dr. Charles H. Herty returned from his negotiations with Dr. Carl von Weinberg at Versailles in 1919 firmly convinced that a much more closely knit organization would be formed.\* Spokesmen for the Cartel repeatedly branded such stories "preposterous," and they talked loudly about the advantages of internal competition as a stimulus to research and sales and manufacturing efficiency. Nevertheless the firms in the Cartel repeatedly and simultaneously increased their capitalization † in response to the falling value of the mark, but always in step with each other.<sup>7</sup> Actual amalgamation was consummated November 28, 1925,<sup>8</sup> and management, under Dr. Carl Bosch of Badische, proceeded vigorously not only to simplify and centralize the internal organization,<sup>9</sup> but also to expand operations into many fields.<sup>10</sup>

Diversification was assiduously cultivated. The Oppau synthetic am-

\* See Vol. III, p. 263.

† Aggregate capitalization was increased Dec. 1917 to 147,600,000 gold marks; in 1919 to 649,900,000. Details of the last three increases in gold marks in millions were as follows:

	1920	1921	1922
Bayer	252	430	470
Badische	252	430	470
Hoechst	252	430	470
Agfa	88	146	159
Griesheim-Elektron	63	108	118
Weiler-ter-Meer	23.3	33.3	36
Cassella	81	153	158
	<hr/> 1011.3	<hr/> 1730.3	<hr/> 1881.0

monia plant, which had been promptly rebuilt after the explosion in 1921, was expanded and high-test nitrogenous fertilizer compounds—Leunasalpeter (ammonium sulfate-nitrate), calcium nitrate, and urea containing 46 per cent nitrogen—were produced and aggressively marketed. The Badische synthetic methanol process was exploited and exports to this country disrupted our wood chemical industry. The Bergius coal hydrogenation process was cultivated chemically, commercially, and politically for all its worth. Although dropped later, only to be taken up again on orders from the Nazi regime, synthetic rubber research was pushed. All this took place within the original companies. Operations were deliberately deployed from the old coal-tar base.

Simultaneously an ambitious campaign of expansion was launched, a program that is interesting in comparison with American methods of diversification-through-merger, which were going on at the same time. Gasoline, plastics, rayon, explosives, and lithopone were the chief fields of invasion. An alliance with the Riebeck'sche Montanwerke, cemented by a 25 per cent stock ownership, led to the foundation of Deutsche Gasolin, in which the I.G. had a half-interest. Together with the Bergius process this gave the new trust a controlling vote in motor fuels. A dominating position in rayon was assured by another alliance with the Glanzstoff-Bemberg interests. The combined group financed a new company for the manufacture of acetate silk and absorbed Köln-Rottweil. The I.G. obtained control of Nobel and Rheinisch-Westfälische, which meant control of explosives. A financial interest with control over the sales organization of the Lithopone Cartel, which had extensive ramifications in the paint field, was also consummated.\*

In distinction to the American chemical mergers of the period, the German trust seldom made an outright purchase. The I.G. was quite content to secure a majority stock interest. In numerous cases even this stock control was not attempted. The reason, no doubt, was the conservation of working capital, enabling the corporation to extend its program of ramification and infiltration with the minimum investment.

This shrewd policy was made practical and far-reaching through cartel agreements. Having secured control of the leading company in a given field, the I.G. was able by these means to extend its influence through ever-widening spheres of chemical activity. Defiance of the all-embracing giant by a smaller company was suicidal, and there was very little popular support in Germany at this time for "the underdog." In fact, the German Government and the German people alike enthusiastically endorsed this rationalization movement, being completely con-

\* See *Chem. Mkts.* 22, 28 (1928) for chart of I.G. companies and subsidiaries, with their principal products; also Trivanovitch, *Rationalization of German Industry*.

vinced that the thoroughgoing integration of the big German industries from raw material to finished product was their economic salvation amid the convulsions of the postwar years. It was a line of thinking that led straight to the state-planning of the Nazi regime.

The Potash Cartel reveals these nationalistic tendencies clearly. The failure of the Potash Syndicate created by the Law of 1910 was due to lack of control over production. The war did not help matters. It broke the natural monopoly by returning the Alsatian mines to French ownership. It left the German industry with deteriorated equipment, lack of labor, disorganized foreign markets, and little buying power at home. When as a result of the Revolution of 1918 the Socialists came into power, everybody expected that the big mining industries, coal and potash, would be promptly nationalized. A commission of nine enthusiastic followers of Karl Marx was appointed to accomplish this task and under its auspices two laws affecting potash were enacted: the Socialization Law of March 23, 1919, and the Law for the Regulation of the Potash Industry, April 24, 1919.<sup>11</sup>

Instead of the expected socialization, these two pieces of legislation compromised the ideal of state ownership with the realities of potash production and sales. They endeavored to put into practice two major conflicting ideas: an organization of the individual companies into a compulsory, centralized, controlled unit and the transformation of individualistic acquisitive economy into a sort of national welfare society. All producers were compelled to join the German Potash Syndicate, and the socialistic ideal was to be achieved through a Federal Potash Council, the Reichskalirat, whose members represented all the various interests: consumers, workers, mine owners, the State.\* This body had complete control of production and distribution. It could shut down mines and it did; thirty of them for fifty years. It could fix prices, and it did not scruple to give special rebates to big American fertilizer companies in order to wipe out the lingering competition from our miscellaneous domestic potash evaporated from the brine lakes of Nebraska and California, snatched from cement plant flue dusts, or extracted from the lees of molasses spent in alcohol production. This omnipotent omnibus council left the active management both of mining and selling in the hands of the businessmen who had previously administered the companies in order, as Stocking suggests, to guarantee "that efficiency in management which is supposed to inhere in the activities of an individualistic economy."<sup>12</sup>

\* The "Kalirat" consisted of 30 members: 5 representatives of the potash producers and 3 each of the Syndicate and the Government; representing the consumers, 4 for agriculture, 2 for the potash trade, and 1 for the chemical industry; 1 representative each for the technical and clerical employees, 8 of labor in the mines and 1 in the chemical industry, with 1 technical expert. (See Stocking, *Potash Industry*, p. 155.)



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The root evil of overproduction from many small, uneconomic producers continued. The Socialist Government hesitated to grub it out drastically by nationalization of the industry, and during the twenties the Kalirat passed various changing regulations covering the closing of mines and the allocation of quotas. The overproduction problem was solved in a thoroughly capitalistic fashion. Encouraged by restricted over-all production and fixed prices, the battle for quotas in turn encouraged the purchase of smaller and closed mines by the larger operators, with the result that by 1929 over 84 per cent of the output was in the hands of three strong operators.\*

In Great Britain the course of chemical consolidation was different: slower than in the United States, but in the end as complete as in Germany. British industrialists, the most experienced and diversified group among all nations, had long since learned the advantages of large-scale production and curbed competition. Nevertheless the sturdy spirit which broke up the guilds and forbade the granting of crown monopolies, fosters independence, and so English manufacturers inclined to personal agreements and voluntary associations of the cartel type rather than mergers or outright purchases.

In many respects, therefore, the chemical consolidations are an exception to the common English practice.† The United Alkali Company in 1890 and the Imperial Chemical Industries in 1926 were both mergers of historic significance. The amalgamation of the 45 different alkali works employing the Leblanc process ‡ was not only the first chemical consolidation inspired by technological competition, but it was also the first large industrial consolidation in Great Britain.<sup>13</sup> The Imperial Chemical Industries, by gathering together four great companies manufacturing heavy chemicals, alkalies, explosives, and coal-tar dyes, was the

\* The capitalization in millions of reichsmarks and of dollars and the production quotas in % were as follows:

	Capital		Quotas
Wintershall	200 M.	\$47.6	41.0
Salzdetfurth	72	17.1	26.8
Burbach	125	29.8	16.4
Preussische Fiskus	140	33.3	9.1
Kali-Chemie	32	7.6	4.2
Deutsche Solvay	75	17.9	2.2
Others	—	—	0.1

Burbach (organized 1928) owned 291 of the 1,000 shares of Wintershall which in turn owned 1,400 of the 4,000 shares of Burbach, so that the concentration was even greater than appears. (See Trivanovitch, *op. cit.*, p. 75, and for production data of German potash, 1913, 1914, 1924-28, Appendix IX.)

† For the history of the British merger movement, see Miall, *History of the British Chemical Industry*, and Levy, *Monopolies, Cartels and Trusts in British Industry*.

‡ The United Alkali Co. celebrated its centenary April 1923, the anniversary of James Muspratt's introduction of the Leblanc process at his chemical plant on the banks of the Mersey near Liverpool. [See *Chem. Age (London)* 8, 29 (1923).]



first broad diversification by means of consolidation, and the *Manchester Guardian* hailed it in an editorial entitled "A British Chemical Trust At Last!"<sup>14</sup>

Behind this consolidation was a broad background of expansion and amalgamation. United Alkali was itself a consolidation. Its chief competitor had been the Brunner, Mond & Company, operating the ammonia-soda process under the energetic leadership of chemically minded Ludwig Mond. His equally vigorous, financially minded son, Sir Alfred Mond (later Lord Melchett) advanced and expanded the Brunner-Mond interests during World War I. They acquired several smaller chemical companies, notably the Castner-Kellner Alkali Company, operating the electrolytic process, and for the British Government they built and operated the synthetic ammonia plant at Billingham-on-Tees. Brunner-Mond's position in this wartime effort to make good the nitrogen deficiency was similar to that of the General Chemical and American Cyanamid Companies' association with our Government in the Muscle Shoals plants. This similarity ended abruptly at the close of the war. Our Government repudiated its options to these companies for the purchase of the nitrogen plants. Years of futile negotiations and political jockeying followed, ending in government operation and the creation of the Tennessee Valley Authority. The British Minister of Munitions, on the other hand, sold the Billingham plant to Brunner-Mond in February 1920. The company organized a subsidiary, Synthetic Ammonia & Nitrates, Ltd., enlarged the operation under the direction of Colonel G. P. Pollitt, and with ammonium sulfate as a starting point, pushed energetically into the fertilizer field.<sup>15</sup> Nobel, dominant in the explosives field, had not only absorbed numerous smaller manufacturers, but it had very naturally branched out into cellulose products, lacquers, artificial leather, and rayon.<sup>16</sup> The British Dyestuffs Corporation \* was a descend-

\*An interesting sidelight on the British official attitude towards this company and consolidations in general is found in the *Report on Dyes and Dyestuffs*, Standing Comm. on Trusts, House of Commons (Cmd. 1370, 1921):

"In view of these great and powerful combinations of dyemaking concerns in Germany, America, and to a lesser degree Switzerland and France, it is a warrantable assumption that the British dyes industry could only be put into a position to compete effectively with its foreign rivals, whether in the home or in neutral markets, by some financial unification of its principal component firms such as that represented by the British Dyestuffs Corporation.

"Holding as we do the view that the giant concern is not necessarily either more efficient, enterprising or economical in its operations than the congeries of smaller concerns competing one with the other, we are, at the same time, impressed, as a result of the evidence we have heard, with the degree to which international competition in dyes (as also to some extent competition within the national frontiers) is a conflict of commercial 'Great Powers' exhibiting all the characteristics of militant diplomacy carried on with financial and commercial brute force in the background, rather than a simple economic matter of striving to offer, in competition with others, the most acceptable article at the most favorable price.

ant of the government-sponsored British Dyes, Ltd., with which it merged after the war and to which were added in 1926 Scottish Dyes, Levinstein, Clayton Aniline, and Read, Holliday.<sup>17</sup>

When in October 1926 these four combines joined in the Imperial Chemical Industries,\* the authorized capitalization reached a figure unprecedented in British finance—£65,000,000.<sup>18</sup> To weld these four strong, independent organizations into a single, harmonious whole was the first essential and difficult task of the management. They went about it in typically British fashion. In sharp contrast to the dictatorial scrapping of plants and shuffling of functions into the logical balanced organization which the I.G. set up, there evolved an elastic corporate form within which various operating units enjoyed a great measure of autonomy.† From the first it was a matter of policy to define the duties of executives, not by setting limits to their authority, but by outlining spheres of activity within which they were supposed to exercise their own judgment and initiative. The result was an early model of highly decentralized executive control exercised broadly by means of declarations of general corporation policies and specific approval of operating budgets, a form of organization associated in this country with Alfred P. Sloan, Jr., and General Motors and exemplified in the chemical field by du Pont.<sup>19</sup>

Imperial Chemical Industries began immediately to expand. The stockholders approved the issue of additional preferred stock to a total not exceeding £6,580,000 and immediately some £270,000 were used in completing the financial details in connection with the purchase of Cassel Cyanide Company, Union Acid Company, Oliver Wilkins & Company, and Casebourne & Company, all of which were taken over by I.C.I. during 1927.<sup>20</sup> The following year the company acquired control or a substantial interest in the Tees Salt Company, Elliott's Metal Company, British Copper Manufacturers, Ltd., Allen Everett & Sons,

"In this *haute politique* of large-scale industry the unassociated group of small concerns, though severally and jointly more efficient as regards mere production, may be at the mercy of the aggressive and predatory policy of the less efficient but financially more powerful rival."

\* The consolidation was effected by the exchange of stock of I.C.I. as follows: preferred, share for share, for preferred of Nobel and United Alkali and 5 for 4 of Brunner-Mond preferred; 3 shares common and 2 preferred for either 2 shares common or 4 deferred of Nobel; 3 for 2 common shares or 1 deferred for 3 common of United Alkali; 3 common with 2 deferred for 2 common of Brunner-Mond; 16 each of preferred and common plus 1 deferred for 40 shares of British Dyestuffs common. The original directors were Sir Alfred Mond, chmn., Sir Harry McGowan, pres., Marquis of Reading, Lord Ashfield, Sir John Brunner, Sir Max Muspratt, Sir Josiah Stamp, H. J. Mitchell, Dr. G. C. Clayton, B. E. Todhunter, Henry Mond, Col. G. P. Pollitt, and J. G. Nicholson. [See photograph, *Chem. Mkts.* 20, 208 (1927).]

† For a firsthand account of the aims and methods of the I.C.I. organization, by a director, see Appendix X.

and shortly afterwards, Canadian Industries, Ltd.,\* Scottish Agricultural Industries, Ltd., and the Mond Nickel Company.<sup>21</sup>

While the German and British chemical industries were thus building up dominating companies, the rationalization movement spread to other European countries. Similar to Imperial Chemical Industries, in that it consolidated the four chief factors in four different branches of chemical activity, the Etablissements Kuhlmann was organized in France in 1928. Kuhlmann itself traced back to a modest sulfuric acid factory built in 1825, and its principal activities included explosives, dyes, rayons, lacquers, to which nitrogenous fertilizers were added during the war. Its associates in the French trust were St. Gobain (heavy chemicals, alkalies, fertilizers, glass, etc.), Pechiney (electrochemicals), and the Nitrogenous & Compositized Fertilizer Company (synthetic ammonia, etc.).<sup>22</sup> In Italy Montecatini became the outstanding chemical operation, a holding company with more than thirty subsidiaries operating throughout all branches of the industrial chemical field. After the war, it went in strongly for fertilizers, rayons, and plastics.<sup>23</sup>

In Central Europe, outside of Germany, Verein für Chemische und Metallurgische Produktion von Aussig, commonly known as the Aussiger Verein, assumed at this time a commanding position, manufacturing some 60 per cent of Czechoslovakia's chemical production and extending its influence throughout a number of adjacent countries. With three plants in Czechoslovakia, Aussig had a virtual monopoly of alkalies, chlorine, potassium and zinc salts, dyes, synthetic ammonia, and lithopone, and it held an important Continental position in tin salts and activated carbon.<sup>24</sup>

That a web of international chemical alliances spread throughout Europe at this time is clearly illustrated by this comparatively small company. It had been organized in 1857 to operate a refinery for potash salts from the Stassfurt mines. A Leblanc soda plant was added, but this was abandoned in 1907 when dyes and heavy chemicals became the centers of activity. In 1905, Aussig joined Solvay et Cie of Belgium in two alkali plants, later participating in similar enterprises in Austria, Rumania, Poland, and Czechoslovakia. In 1911 it acquired Continental rights outside of Germany to the Goldschmidt process for the recovery of tin from scrap and the manufacture of the chloride. The discovery of a process for making alizarin red in the Aussig laboratories gave it a trading point with the old German dye companies with which it entered into a close alliance. Its war-built carbide and cyanamide plants gave it a foothold in this field, and in the postwar period, Aussiger Verein entered into the European cartels on activated carbon, tin salts, and

\* Through Nobel, I.C.I. had already a part, but not 100% interest in Canadian Industries.

lithopone. It also acquired a substantial interest in a Bohemian rayon factory, in pharmaceutical chemical plants in Yugoslavia and Hungary, in the Torda heavy chemical operations in Yugoslavia, and in the electrochemical works in the German Salzbergwerk Neustassfurt near Bitterfeld in Central Germany.

The emergence of a single, gigantic, widely ramified chemical company in each of the principal European countries inevitably simplified and strengthened scores of such international alliances. It suggested others. Furthermore, such alliances, usually in the form of a cartel, were greatly encouraged by the widespread belief that economic good health was only to be achieved in disrupted Europe through closely integrated production and controlled competition. This conviction was strengthened by the nationalistic ideals which burst forth after the signing of the Versailles Treaty and by the new knowledge of the economic and military importance of chemical products. The international race in plant building and grants for research, and indirectly in preferential tax or freight rates, were all expressions of this nationalistic chemical spirit.

During 1926, when international cartels were organized in such basic commodities as aluminum, steel, copper, tires, fertilizer, potash, carbides, and glue,<sup>25</sup> the I.G. successfully negotiated trade agreements with Russian, Spanish, and Japanese dye and chemical industries. It had also begun serious conversations with British and French interests.<sup>26</sup> In view of the almost universal distrust in which the Soviet Government was held at this time, the Russian contract is particularly interesting. It was to run for three years, and it gave to the I.G. 70 per cent of all Russian imports of both coal-tar dyes and medicinals, guaranteeing the Germans certain gross sales in return for their maintaining stocks in Russia, provided that in return the Germans would give technical assistance in the development of the Russian chemical industry. Upon its expiration in 1929 this agreement was not renewed. The Russians complained that they had not received the promised technical assistance: the Germans charged that the agreed share of the market had not been reserved for them.<sup>27</sup>

The terms of the German-French-Swiss dye cartel, in so far as they covered foreign trade, soon became fairly obvious. The Germans, who had long been active in Oriental markets, were allotted this rich territory. The French acquired a preferred position in South America while Switzerland had a priority in Southern Europe. A formal cartel agreement between the three on substantially these terms was executed in 1928.<sup>28</sup>

In the spring of 1927, only seven months after formal organization of Imperial Chemical Industries, Sir Alfred Mond visited Germany and reports reached this country that the dominating British and German

companies had reached a working agreement on dyes which went so far as to include an exchange of patents, some control over production, and agreements as to marketing in foreign fields.<sup>29</sup> Since an alliance between the I.G. and the Swiss and French dyemakers was already in effect, a closer, all-European dyestuff cartel was the inevitable conclusion.

The American dye industry found itself isolated in export business, facing a very powerful combined front. Its position was the more uncomfortable because it had been unable to get together to organize an export association under the Webb-Pomerene Act. In this respect the dyemakers were in no better position than the heavy or fine chemical manufacturers. Even the alkali, sulfur, and phosphate rock groups, which had formed such export associations, found that they were bound to be handicapped in competition with the closely knit cartels which were being rapidly built up in all sorts of chemical products from alum to zinc. Naturally, therefore, the growth of strong chemical trusts which came to agreements in international cartels, caused grave concern to leaders of the American chemical industry.

Just at this time two important, international conferences were held in Europe that did nothing to allay these apprehensions. The League of Nations held an international economic conference in Geneva during May 1927. It was learned with dismay in this country that the League subcommittee on chemicals had delegated to Germany the task of preparing a monograph on the chemical industry which was to serve as the agenda of the meeting. This document, signed by Dr. C. Ungewitter,<sup>30</sup> manager of the chemical group of the German Manufacturers' Association, had been completed September 30, 1926, and had been submitted to the French and British chemical trade associations, both of which had replied with criticisms and additions.<sup>31</sup> Although invited through the Chemical Advisory Committee of the Department of Commerce to attend the conference, American chemical manufacturers had had no opportunity to read or comment upon this important document. In fact, news of its existence reached this country only through stories published in the British chemical trade press.

The obvious explanation that the United States was not a member of the League of Nations did not satisfy the representatives of the Manufacturing Chemists' and the Synthetic Organic Chemical Manufacturers' Associations who met in Washington at the call of the Chemical Advisory Committee.\* It was forecast that the Germans would attempt

\* A. Cressy Morrison at the time chmn. of the Comm., met with S. W. Wilder, Chas. L. Reese, W. D. Huntington, P. S. Rigney, Geo. F. Hasslacher, and J. I. Tierney of the Mfg. Chem. Assoc.; August Merz, W. S. Weeks, W. F. Harrington, Fred G. Zinsser, and Chas. A. Mace, of the Synth. Org. Chem. Mfrs. Assoc. Also attending were Jas. A.

to use the Geneva conference and the backing of the League to further the idea that each country confine itself to the field in which it was best suited to serve the whole world; the United States, steel; Germany, chemicals.\* In workaday reality, this meant a concerted attack upon tariffs, specifically upon the American tariff. It was not that the Fordney-McCumber rates were the highest, for Ungewitter's own figures showed eleven countries had higher tariff schedules,† but that the United States was the greatest importer of chemicals and our market therefore of paramount value.

After a warm indignation meeting, the Committee issued a statement to the press in which it reiterated the apprehensions about the League of Nations chemical conference and urged against a reduction of our chemical tariff which would jeopardize a domestic supply of essential materials.<sup>32</sup> As a result of this meeting President Hoover appointed A. Cressy Morrison and Dr. Charles L. Reese special chemical advisors to accompany the five American delegates to the Geneva Economic Conference.<sup>33</sup>

Deliberations at Geneva centered about the higher chemical tariffs adopted by almost every country since the war.<sup>34</sup> A cautiously worded resolution was adopted deploring this tendency toward economic isolation. Decisive, effective action was blocked by the lukewarm support of Great Britain and very active opposition of most of the smaller nations, headed by the French. These countries had not forgotten the lesson of chemical unpreparedness and all were anxious to establish, in so far as possible, their own chemical self-sufficiency. Cartels were

Rafferty of Carbide and Carbon Chemicals, and Chas. C. Concannon and Thos. W. Delahanty of the Chemical Div., Dept. Com. For officers of both associations, see Appendix XLIX.

\* "I recall that Cressy Morrison phoned me, asking that I call at his office to pick up an important, confidential document. I did this after promising to keep its contents inviolate. I was asked to prepare an opinion and return it with the original in 24 hours. Obviously the 100 or more pages could not be digested in that time, but fortunately the bulk was composed of statistics which had to be accepted at face value. Reading the arguments, such as they were, led to the conclusion that as usual Germany argued that what was best for Germany was best for the world. That was my report. It was my original thought, but since then I have seen it repeated. Probably I was not as original as I thought. It was probably equally obvious to many others." (August Merz, to author, Jan. 20, 1946.)

† On the basis of "ad valorem equivalents" expressed in percentage:

United States	40.0	France	80.9
Japan	50.6	Brazil	84.9
Bulgaria	57.4	Chile	87.1
Serbia	65.5	Poland	112.6
Greece	65.7	Russia	137.1
Argentina	70.3	Spain	158.3

Dr. Ungewitter's table omitted Great Britain because "that country has decreed a general import prohibition on aniline dyes and by-products." [See *League of Nations C.E.I. Doc. No. 10*, 37 (1927); quoted, *Chem. Mkts.* 20, 698 (1927).]

also discussed,<sup>35</sup> but again the conference dodged the issue. A mealy-mouthed resolution was adopted, calling attention to the divergent views of the delegates and concluding that international control of cartels was inopportune and that combinations should be judged by the spirit in which they are carried out rather than upon the basis of abstract principles. So the widely heralded Geneva Economic Conference, attended by the delegates of 47 nations, with observers present from the United States and Russia, accomplished little.

From the point of view of the American chemical industry, less came forth from the meetings of the International Chamber of Commerce at Stockholm, June 28 to July 9. This large and ambitious gathering, which was attended by Charles H. MacDowell as representative of the Manufacturing Chemists' and the National Fertilizer Associations, also deplored the rising tariff barriers, but its attitude toward international cartels was distinctly friendly.<sup>36</sup>

The result of these two meetings was to publicize and give the stamp of semiofficial approval to European criticisms of the Fordney-McCumber Tariff. Particularly in Germany this grew to active propaganda blaming the United States for the economic ills of the rest of the world. Tacit approval of trusts and cartels was but to be expected. Most of Europe at that time was enthusiastically rationalizing its own industries, thoroughly convinced of the advantages of large-scale operations and the necessity of curbing competition. It was a policy that led to high tariffs to protect the home market and unilateral trade agreements to assure a share of the export business.

#### REFERENCES

1. Trivanovitch, *Rationalization of German Industry*, pp. 30-31.
2. Liefmann, *Cartels, Concerns and Trusts*, p. 7; Pöfibrum, *Cartel Problem*, pp. 10-15.
3. Liefmann, *op. cit.* pp. 8-13; L. T. Fournier, *Chem. Mkts.* 22, 33 (1928); J. G. Frederick, *ibid.* 39; T. J. Kreps, *Am. Econ. Rev.* 35, 297 (1945); G. S. McClellan, *For. Policy Repts.* 178 (Oct. 15, 1944).
4. Liefmann, *op. cit.* p. 22.
5. Alien Property Custodian (A. M. Palmer), *Ann. Rept. 1918-19*, Chap. on chemical industry, in *J. Ind. Eng. Chem.* 11, 352-65 (1919).
6. Trivanovitch, *op. cit.* pp. 31-32.
7. *Drug Chem. Mkts.* 8, 1112 (1921), 9, 27 (1922); Hearings Judiciary Comm. (S. 67:2) on Dye Monopoly, 1922, p. 85.
8. *Drug Chem. Mkts.* 17, 985 (1925); O.P.D. *Reptr.* 21 (Oct. 1, 1925); Tariff Comm., *Census of Dyes, 1924*, p. 9, 1926, p. 150; W. T. Daugherty, Bur. For. Dom. Com., *Trade Inform. Bull. No. 451* (1926) & No. 532 (1928).
9. Brady, *Rationalization Movement in German Industry*, pp. 237-40; Haynes, *Chemical Economics*, pp. 235-36.
10. Brady, *op. cit.* pp. 240-45; Trivanovitch, *op. cit.* pp. 123-30; Tariff Comm., *Census of Dyes, 1927*, p. 148, 1928, p. 148, 1929, p. 153.
11. Stocking, *Potash Industry*, p. 152; H. M. Hoar, Bur. For. Dom. Com., *Trade Prom. Ser. No. 33*, pp. 23-30; see also Vol. II, p. 178.
12. Stocking, *op. cit.* p. 154; Brady, *op. cit.*

- pp. 245-49; Trivanovitch, *op. cit.* pp. 71-75; Liefmann, *op. cit.* pp. 214-17.
13. Miall, *History of British Chemical Industry*, p. 20.
14. Oct. 28, 1926; see also *Chem. Age (London)* 15, 413 (1926).
15. *Ibid.* 20, 402 (1929).
16. Levy, *Monopolies, Cartels and Trusts in British Industry*, p. 261.
17. *Ibid.* p. 262; Miall, *op. cit.* p. 61.
18. *Chem. Age (London)* 15, 416, 451, 558 (1926).
19. Haney, *Business Organization and Combination*.
20. H. S. Fox, Bur. For. Dom. Com., *Trade Inform. Bull. No. 545*, 7 (1928); *Chem. Age (London)* 17, 628 (1927); *Chem. Mkts.* 22, 27 (1928).
21. *Chem. Age (London)* 19, 600 (1928); Fox, *op. cit. Bull. No. 621*, 1 (1929); Haynes, *op. cit.* pp. 247-48.
22. D. J. Reagan, Bur. For. Dom. Com., *Trade Inform. Bull. No. 652*, 3 (1929); Reagan and E. C. Taylor, *ibid. Bull. No. 726*, 3 (1930); Haynes, *op. cit.* p. 248.
23. E. Humes, Bur. For. Dom. Com., *Trade Inform. Bull. No. 705*, 3-11 (1930).
24. Daugherty, *ibid. Bull. No. 708*, 4-7 (1930).
25. *Ind. Eng. Chem.* 20, 282 (1928); L. H. Marks, *Chem. Mkts.* 30, 229 (1932).
26. Tariff Comm., *Census of Dyes, 1926*, p. 150; see also Trivanovitch, *op. cit.* pp. 125-28.
27. Tariff Comm., *Census of Dyes, 1929*, p. 156.
28. *Ibid.* 1928, p. 145; orig., Dept. Com., *Ann. Rept.*, July 22, 1929.
29. *Chem. Mkts.* 20, 711 (1927); *Chem. Met. Eng.* 34, 321, 387 (1927).
30. League of Nations, *C.E.I. Doc. No. 10* (1927); abstr., *Chem. Mkts.* 20, 695 (1927).
31. *Chem. Mkts.* 20, 641 (1927).
32. *Ibid.*
33. A. Cressy Morrison, to author, May 13, 1946.
34. E. J. Mehren, *Chem. Met. Eng.* 34, 322, 356 (1927).
35. L. Domeratzky, Bur. For. Dom. Com., *Trade Inform. Bull. No. 556*, 57 (1928).
36. *Chem. Mkts.* 20, 804 (1927); 21, 289 (1927).





*PART TWO*  
INORGANIC CHEMICALS



## Chapter 5

### CONTACT ACID FROM BRIMSTONE

CONTACT PROCESS SUPERSEDES CHAMBER AS MONSANTO, SELDEN, AND GENERAL CHEMICAL PROMOTE VANADIUM CATALYSTS FOR HIGH-TEST ACID—BRIMSTONE OUTPUT DOUBLES WAR RECORD—NEW GULF COAST SULFUR DOMES TAPPED: HOSKINS BY FREEPORT, PALANGANA BY DUVAL, BOLING BY TEXAS GULF—SULEXCO-SICILIAN CONSORTIUM AGREEMENT STABILIZES WORLD MARKET—BY-PRODUCT SULFUR SOURCES COMMERCIALIZED—RIO TINTO RE-ENTERS AMERICAN PYRITES MARKET.

**M**AKERS OF HEAVY CHEMICALS, because their plant investment is high and the selling price of their products low, always have good dollars-and-cents reasons for "running the old apparatus to death." Accordingly, new processes and improved equipment tend to be introduced chiefly in the new installations, and thus the rate of obsolescence sets the pace of progress. To move this natural inertia requires technical or commercial changes of extraordinary force. During the 1920's a powerful combination of both incited radical developments in the American sulfuric acid industry.

The shift from pyrites to sulfur as a raw material and adoption of the contact process, both began during World War I, the outcome of unavoidable wartime conditions. Both innovations extended their influence in the postwar decade. The introduction of vanadium catalysts for contact acid was a major revision in technical practice. The recovery of sulfur from gasworks and new uses for strong sulfuric acid in dye, rayon, lacquer, plastics, and other fields resulted in a revaluation of the commercial status of both the raw material and its chief chemical product.<sup>1</sup>

At the close of the war half of the American sulfuric acid was made from brimstone: by 1929 more than two-thirds.\* During the expansive prosperity that began in 1922 production of sulfuric acid rose rapidly. By 1929 † the output was double what it had been in 1915, a record high

\* As estimated by Kreps (*Economics of Sulfuric Acid Industry*, p. 105) the percentage of sulfuric acid from various primary raw materials was:

	Sulfur	Pyrites		By-Product of Zinc and Copper Smelters
		Domestic	Foreign	
1919	48	15	21	16
1925	68	6	13	13
1929	69	7	10	14

† For production, value, and number of establishments, 1923-29, see Appendix XI-XII; for distribution of this acid as consumed by various industries, Appendix XIII.

of 8,491,114 short tons of 50 Bé. acid.<sup>2</sup> Petroleum refining, rayon, cellulose film, fertilizers, textiles, and metallurgy contributed largely to this increased consumption.

The realignment of sulfuric acid technology was a compulsory re-adjustment initiated by war conditions that could not be denied. The contact process won its way because of its simpler operation, its adaptability to continuous automatic production, and its ability to produce high-test material for which there was now a domestic market.\* But its adoption would not have been permanent had it not been for the ready supply of virtually pure brimstone from the Gulf Coast mines and the timely perfection of vanadium catalysts.

Oxidation of  $\text{SO}_2$  to  $\text{SO}_3$  by means of vanadium catalysts was no jack-in-the-box discovery. It evolved gradually after 1895, when Johann J. Walter used vanadium pentoxide as a catalyst in the vapor-phase oxidation of toluene and anthracene, and as early as 1899 R. Meyers proposed vanadic acid as a catalyst in making sulfuric acid, a process which was patented by Carl J. E. de Haën.<sup>3</sup> The subsequent history is written in the patent literature. As the commercial exponent of the contact acid process, the Badische organization had good reason to learn the limitations of the platinum catalysts then in use and to seek a cheaper, more available material less susceptible to poisoning by the metallic impurities commonly found in sulfur-bearing materials. From these researches<sup>4</sup> came a catalyst prepared by impregnating inert material with a solution of vanadates.† This was promptly patented in Germany and England in the names of Franz Slama and Hans Wolf.<sup>5</sup> Application was filed in the United States, October 9, 1914, but the war having intervened, this

\* "I question whether you are correct in ascribing the success of the contact process to simpler operation and adaptability to continuous automatic production. The operation is neither simple nor automatic, and some contact process plants have become notorious for their frequent shutdowns, on account of which they are able to operate only about 85 per cent of the time. The contact process really won its way because of increasing demand for high-strength and fuming acids, and because of high-pressure salesmanship. Now that manufacturers have had 15 or 20 years' experience with it, they are coming back to the chamber process." (Andrew M. Fairlie, to author, Apr. 8, 1946.)

† During the war, H. H. Meyers, Armour & Co. fellow at the Mellon Inst., at the suggestion of C. H. MacDowell experimented with the waste alumina from the tailings of Armour's Marysville alunite potash plant as a catalytic mass. He found that impregnation with a vanadium salt gave a satisfactory substitute catalyst for the almost unobtainable platinum mass, and U. S. Pat. 1,420,203, filed Jan. 20, 1919, was granted MacDowell and Meyers, June 20, 1922, ass. to Armour. A 5-ton plant, designed by March F. Chase, was built alongside the Armour chamber plant at Nashville by a subsidiary, Tennessee Chemical Co., and operated successfully several months later in 1918. The end of the war caused its abandonment, and after MacDowell's retirement in 1932, this patent was sold to Allied. (C. H. MacDowell, to author, Feb. 10, 1946; see also *Official U. S. Bull.*, Dec. 19, 1918.)

patent was not granted until 1921, when it was issued assigned to the General Chemical Company.<sup>6</sup>

Two years later the storm center of the American development of vanadium catalysts reached this country in A. O. Jaeger.\* Formerly a Badische chemist, he went to work in the laboratories of the National Aniline & Chemical Company at Buffalo. In 1925, having invented a vanadium pentoxide zeolite, he contracted with the Monsanto Chemical Works to prepare this material in its laboratories and test it on a semi-plant scale. He was accompanied to St. Louis by his compatriot and associate, J. A. Bertsch, and the two prepared and demonstrated their contact mass, so that on June 8, 1926, Monsanto notified them that it would exercise its option to purchase the patents. Ten patents covering these researches were issued to Jaeger, the key one for the so-called Monsanto contact mass being U. S. Pat. 1,657,754 (1928).

Failing to come to terms with Monsanto on a continuing contract of employment, Jaeger became technical director of the Selden Company, and in 1927 a new catalyst, containing 7 per cent vanadium pentoxide was introduced to the American sulfuric acid makers as the Selden vanadium mass. This was patented by Jaeger,† and Monsanto promptly sued for alleged infringement of its rights. Judge W. H. S. Thomson in the U. S. Court, Western District, Pennsylvania, ruled that the contract with Monsanto covered only the option and agreement to demonstrate a vanadium contact mass invented prior to the agreement.<sup>8</sup>

On the heels of this lawsuit came another. General Chemical Company, which in 1928 began manufacturing vanadium catalysts in substantial quantity, brought suit during the summer of 1929 against Selden, charging infringement of the Slama-Wolf patent. This case was not finally adjudicated until 1932, when Judge Nelson McVicar<sup>9</sup> found for the Selden Company.†

This controversy was echoed in Europe where a spirited argument enlivened the pages of the German publication, *Metallbörse*, between representatives of Badische, Graesser-Monsanto, and Selden.<sup>10</sup> The Germans maintained with heavy sarcasm that Jaeger had simply carried to the United States knowledge of thoroughly standard catalyst practice in the Badische plant. This seems hardly fair. Greatest credit is due to Badische for the first preparation of a practical vanadium catalyst, the Slama-Wolf mass, and its actual use since 1914, nevertheless, unless

\* Alphons Otto Jaeger, born in the Palatinate, Ger., Oct. 14, 1886, educated at Zurich (B.S., 1911) and Basel (Ph.D., 1913), was with Badische, 1919-23. When Selden was absorbed by American Cyanamid, he became chmn., development comm.

† General Chemical appealed to the Circuit Court of Appeals and Sept. 20, 1933, Judge Buffington affirmed the ruling of the lower court, going so far as to declare the Slama-Wolf a "paper patent." Subsequent petition for writ of certiorari for review by the Supreme Court was denied.

there was a great deal of secret know-how not disclosed in the German patents of 1913, Jaeger's work both at Monsanto and at Selden did reveal true invention as adjudicated by the court and substantiated by competition between the three American companies: General Chemical, Monsanto, and Selden.

Monsanto and Selden both pushed the erection of contact acid plants and the sale of their vanadium catalysts. By 1928 five such plants had been built by the former in Missouri, Oklahoma, Pennsylvania, and Wisconsin. The first plant using the Selden mass was built for the Standard Acid Works\* at Baltimore by the Chemical Construction Company which had exclusive Selden rights, and which in 1928 received contracts for eight plants with a combined daily capacity of over 800 tons of 100 per cent acid. Every new contact plant installed that year was designed to employ vanadium catalysts.<sup>11</sup>

While the most widely used platinum catalyst during the 1920's was the Grillo-Schroeder platinized magnesium sulfate, this period saw the development of an American platinized mass which curiously had its first industrial trial in Belgium in May 1926.<sup>12</sup> Based upon the discovery of Walter A. Patrick,† this employed a silica gel impregnated with a solution of a suitable platinum compound, such as ammonium chloroplatinate, then dried and activated by heat. The work was done by the Silica Gel Corporation, in which the Davison Chemical Company owned 49 per cent of the outstanding capital stock at first but subsequently sold much of it, while maintaining a close working arrangement relative to financing, engineering, research, and the manufacture of silica gel.<sup>13</sup> In 1927 the Davison Company erected a contact sulfuric acid plant using the silica gel catalyst to fulfill its contract to supply 20,000 tons of acid to the Bethlehem Steel Corporation's near-by Sparrows Point and Steelton mills.<sup>14</sup> Two years later, after this new plant was in operation, the Company announced<sup>15</sup> that in the future all of its installations would be made along these lines.‡ At the time its Curtis Bay works had a daily capacity of about 1,000 tons 50° Bé. acid, divided between six chamber

\* For firsthand account of this historic installation, see memo from Geo. A. Whiting in Appendix XIV.

† Patrick was Johns Hopkins' assoc. prof., 1917; prof. chem., 1924 to date. He previously taught at Mass. Inst. Tech., Syracuse, and Univ. Coll., London, and won his degrees at Syracuse (B.S., 1910; Hon. D.Sc., 1935) and Göttingen (Ph.D., 1914). He was born in Syracuse, N. Y., Jan. 6, 1888.

‡ To exploit the various uses of silica gel, the Colloidal Products Co., Baltimore, was organized, and in 1926, when Warner D. Huntington, Davison vice-pres., was elected pres., succeeding Warren H. Turner, \$150,000 additional working capital was provided by the outside sale of common stock. Two years before the British rights to the Patrick patents had been sold for \$750,000 cash and 51% of the stock in Silica Gel, Ltd. This contract specifically excluded the applications of silica gel in petroleum refining. Over \$5,000,000 was spent by the Silica Gel Corp. in the development of silica gel and its many uses. [See *Drug Chem. Mkts.* 14, 257 (1924); 18, 1079 (1926).]

and three contact silica gel units. In the chamber units Davison had put on line in 1928 an ammonia nitration system developed by du Pont, one of the first installations of its kind, outside of du Pont plants, in the country.<sup>16</sup>

The substitution of ammonia for the old niter-pot process (nitrate of soda) in the nitration step of the chamber process had been introduced in England during World War I. Because of its convenience and markedly lower costs \* it spread rapidly in Europe. Its introduction into the United States was slower. In 1925 only three or four sulfuric acid plants had adopted the method, but in 1926 the sharp cut in the price of ammonia resulted in the installation of this method by many acid makers, the favorite apparatus employed at the time being that developed by E. I. du Pont de Nemours & Company for anhydrous ammonia and by the Chemical Construction Company for ammonia liquor.<sup>17</sup>

Two other sulfuric acid processes appeared here during the twenties. In 1923 the Chemical Construction Company secured rights for the United States and Canada to the Schmidel process † for which was claimed great efficiency in handling gas of variable or low sulfur dioxide content.<sup>18</sup> During the early twenties three Armour Fertilizer Works plants were equipped with Mills-Packard chambers, ‡ an English invention of a unique guttered design. The lowest operating cost of any brimstone-burning operation was claimed by the management, and an installation of two groups of three of these chambers each was made by the American Zinc Company at its East St. Louis plant.<sup>19</sup>

During the closing years of the 1920 decade, sulfuric acid having surmounted the peak of wartime production, there was naturally a great deal of expansion. § New plants appeared in new territories, as the operation of the Louisiana Chemical Company at Baton Rouge started in 1925

\* As estimated by Fairlie, costs of nitrating a ton of 60° B $\acute{e}$ . acid by  $\text{NaNO}_3$  are 37¢; by  $\text{NH}_3$ , 19¢, representing 4.12% and 2.13% resp., of total cost. (See *Sulphuric Acid Manufacture*, p. 150.)

† U. S. Pats. 1,399,526 (1921) and 1,512,863 (1924) issued to Theodore Schmidel and Hans Klencke of Germany.

‡ "Our people still feel that the water-cooled Packard tower chamber plant is superior to the contact plant for the manufacture of superphosphate. The U. S. Phosphoric Products Corp. (a Tennessee Copper subsidiary), producing triple superphosphate at Tampa, Fla., built two contact plants when starting the enterprise, but subsequently when enlarging, put in Packard tower plants. We were the first to install Packard plants, one at Jacksonville and a later one at Wilmington. These plants, which secure full yields in the summer, are especially desirable in the South. They run on 2½ ft. of chamber space per lb. sulfur burned, with low niter consumption; are constructed in the open with no housing, reducing fire risk and construction cost. The older chamber plants, when I last checked up, worked on from 6 to 9 cu. ft. per lb. sulfur burned, although some Armour plants do better." [C. H. MacDowell, to author, Feb. 10, 1946; see also *Ind. Eng. Chem.* 19, 644 (1927).]

§ For list of U. S. sulfuric acid plants, 1929, see Appendix XV.



and taken over by the Consolidated Chemical Industries in 1927.<sup>20</sup> Typical of the expansion of the older companies were the new plants Grasselli built near Detroit and at Wurtley, Kentucky, and reopening of the Terre Haute zinc-acid operation.<sup>21</sup> New contact units were built by the General Chemical Company between 1925 and 1928 at Buffalo, St. Louis, and at Newell, and commercial production of oleum was started in 1927.<sup>22</sup> In 1928 Monsanto revamped the old works and built a new acid plant at Monsanto, Illinois.<sup>23</sup>

One of the most important smelter plants was the new \$600,000 acid installation by the National Zinc Company, Bartlesville, Oklahoma.<sup>24</sup> In the Baltimore district, the two chamber acid units of the Standard Wholesale Phosphate Company of which George A. Whiting was president, were expanded by the construction of the first contact plant in the section, followed next year by a second contact unit.<sup>25</sup> This installation led to the formation of the Standard Acid Works, the sales being principally to the fertilizer manufacturers of the Baltimore area for the production of superphosphate. A process invented by Henry S. Marsh and Ralph Cochran of the Sharon Steel Hoop Company for the economic recovery of sulfuric acid from the pickling liquors of steel mills was the basis of a new company, American Copperas Company, formed by Robert Bentley, a director of the Youngstown Sheet & Tube.<sup>26</sup>

Widespread adoption of the contact process influenced acid makers in their choice of sulfur-bearing materials. The shift from pyrites to brimstone, which began in response to inexorable war conditions, was furthered by technical considerations important in the new manufacturing methods and by greater adaptability to the production of high-strength acid. In the last analysis, however, it was the cost ratio between these rival raw materials that was the clinching argument. And sulfur held the cost advantage not only as a source of sulfur dioxide, but also in its conversion to acid.<sup>27</sup>

The cost differential \* between sulfur and pyrites was usually based

\* In 1917 A. E. Wells and D. E. Fogg (Bur. Mines, *Bull. No. 184*, p. 25) estimated the costs of the competing materials as sources of sulfuric acid as follows:

<i>Item</i>	<i>Pyrites</i>	<i>Sulfur</i>
Material equiv. to 10 tons S	23.3 tons 45% pyrites fines @ \$6.75 ..... \$157.25	10.1 tons @ \$18.50. \$187.00
Handling & roasting ore	\$1.10/ton ..... 25.65	60¢/ton ..... 6.06
Handling cinder	17.5 tons @ 25¢... 4.37	—
Repairs & depreciation burner plant	10% ..... 6.00	10% ..... 1.00
Total expense	\$193.27	\$194.06

These are wartime figures, the ratios in favor of sulfur—1:2 in tons of material handled and 1:5 in conversion costs—are basic.

upon the assumption that in plants of identical size from 25 to 30 per cent more acid could be produced if brimstone were used and that the yield of acid per ton of actual sulfur content of the raw material needed was generally about 4 per cent greater. With brimstone, consumption of niter was also approximately one-half of that required when making acid from pyrites. The number of men required in a pyrites-burning plant was about two and one-half more than needed to operate a sulfur-burning plant. The maintenance cost of the chambers was about four times as great when burning pyrites and depreciation charges were about 65 per cent higher per dollar of capital invested. Finally capital costs of pyrites-burning installations were sometimes twice those of brimstone units of equal capacity.<sup>28</sup>

The return of peace emphasized the cost factor and during the reconversion a new balance was struck between the two rival raw materials. The end of hostilities did not at once end the shortage of pyrites. Contrariwise the sharp cutting off of war demands left sulfur in oversupply, putting the sulfur producers in a difficult position. At the behest of the War Industries Board, to forestall a critical shortage of this vital material, the two producing companies, Union and Freeport, had accumulated aboveground a combined stockpile of nearly 2,000,000 tons. This was eight years' supply for the prewar demand. On top of their current production was now added the output of 300,000 tons a year from the Big Hill Dome of the new producer, the Texas Gulf Sulphur Company. In 1919, 1,190,575 tons of brimstone were brought to the surface, but only 453,646 were sold to consumers. The war demand for acid had disappeared and large surplus stocks of government-owned acid had yet to be absorbed. To cap the climax foreign pyrites began to appear on the market. The price of sulfur dropped to \$16 a ton at the mines in 1921 and to \$14 in 1923.

The future of American sulfur appeared to be dismal and threatening, yet it came through the critical period triumphantly. It won from pyrites the lion's share of the acid market and sulfuric acid consumption zoomed to a new record in 1929. Simultaneously the two industries which are the heaviest direct users of sulfur, paper and rubber, both markedly raised their purchases during these ten years. With the growth in domestic consumption of sulfur, exports increased almost tenfold to 855,183 short tons in 1929, so that this fateful year American production of brimstone was more than twice the record set under every stimulus of war demands in 1918.\* This mounting stream of molten sulfur from the Gulf Coast mines was accomplished by the tapping of three new domes.

\* For U. S. statistics of sulfur production, imports, and exports, 1923-29, see Appendix XVI.

From the delta of the Mississippi to the mouth of the Rio Grande the Gulf Coast was humming with sulfur activity. The original Frasch patents had expired. In the famous suit, *Union Sulphur Company vs. Freeport Sulphur Company*,<sup>29</sup> the Circuit Court held that the supplementary patents, while covering valuable improvements in the hot-water technique, disclosed no true invention and were accordingly invalid.<sup>30</sup> When the Supreme Court refused to review this decision in favor of Freeport, the door was opened for unrestricted use of the Frasch process.

Common knowledge that the wells at the original mine of Union in Louisiana were spluttering towards approaching exhaustion, was a broad hint of opportunities in this field. The Union Sulphur Company itself authenticated this open invitation. During 1920-21 it tested the Palangana Dome in Duval County, near the Mexican border; investigated three others; and optioned sulfur rights at Damon Mound from the Texas Exploration Company.<sup>31</sup> No wonder every rise of land in the region was drilled by optimistic sulfur prospectors. Many of these distinctive landmarks on the flat coastal plain had thrown up yellow signs of the mineral. Now the improved methods of geophysical prospecting were employed to locate salt domes that gave no surface indication of their presence. Between 1924 and 1928, 64 prospective domes were discovered,<sup>32</sup> only four of which, Grande Ecaille, Long Point, Orchard, and Clemens, have since been worth commercial development.

Amid wild rumors of fabulous discoveries and new ten-million-dollar mining companies, one report gravely disturbed all three sulfur-producing companies. Hoskins Mound in Brazoria County, was being deliberately prospected for sulfur for the Texas Company by Spencer C. Browne, whose tests and reports at Bryanmound and Old Gulf earned him a deserved reputation as the outstanding appraiser of sulfur deposits. This mound had been previously exploited for oil and a few shallow wells brought into short-lived production.\* Despite these discouraging failures, in May 1915, the Producers Oil Company, an operating subsidiary of the Texas Company, leased this property. Their chief geologist, E. G. Woodruff, believed that oil would be struck by deep drilling along the flanks of the salt dome.<sup>33</sup> The third well drilled went through a sulfur-bearing formation 200 feet thick, but none of the Producers' crew considered this exceptional showing of sulfur sufficiently interesting to justify taking a sample or making a single analysis. Two other wells indicated quantities of sulfur belowground. But they attracted no attention until in June 1918, when at 900 feet, the drills ran into 20 feet of almost pure sulfur. J. E. Schroeder, the field boss, formerly a Union Sulphur driller, called this phenomenal showing to the attention of C. N.

\* For details, see Haynes, *Stone That Burns*, pp. 183-97; for geology, A. H. Marx, *Bull. Am. Assoc. Petr. Geol.* 20, 156 (1936).

Scott, the Texas Company's vice-president in charge of production. Two light drilling rigs were called in and a deliberate hunt for sulfur started. At the time, Scott wrote to the Texas president, E. C. Lufkin, "This looks like the biggest thing that we have uncovered in a long time."

Spencer Browne was called in as a consultant and to secure accurate cores, he installed his "return-flow" system and set up an analytical laboratory. W. T. Lundy, who had set up as a consulting engineer in San Francisco, was recalled to take charge of the tests as he had previously done at Old Gulf. On the strength of Lundy's report, Colonel William Couper was engaged to draw plans for a Frasch sulfur-mining plant at Hoskins Mound. However, the Texas Company management was loath to undertake so chancy a venture in a new field, so they approached the Texas Gulf Sulphur Company. No agreement could be reached as to the value of the sulfur deposit, and Hoskins Mound was offered to the Freeport Sulphur Company.

Warned by the coming exhaustion of the Union mine, E. P. Swenson was distinctly interested. He had previously turned down an opportunity to purchase Big Hill, now being actively developed by Texas Gulf, and he was of no mind to let another opportunity slip by. Accordingly, on March 4, 1922, the Freeport Sulphur Company took over from the Texas Company its Hoskins Mound leases in so far as they related to sulfur and agreed to have a Frasch plant in production within one year. Construction work was delayed by a flood of the Brazos River which upset the operations at Freeport, and when Homer S. Burns finally moved over to build the new plant, Saturday, March 31, one day before the deadline, the first well pumped sulfur.<sup>34</sup>

With a boiler capacity of 8,400 horsepower, and accessory services including a 280,000,000-gallon reservoir fed through a gravity canal from Bastrop Bayou, the new plant had cost \$2,000,000.<sup>35</sup> Because of the position of the sulfur horizon on the flanks of the dome and the formation of the caprock, operating difficulties developed, and P. George Maercky, then acting general manager, suggested that Spencer Browne be invited to take charge of operations. Having been closely associated with Bernard Baruch and Seeley W. Mudd in various mining enterprises, Browne declined to become a direct competitor of the Texas Gulf Sulphur Company, so the position was offered to his associate, W. T. Lundy.\* After struggling manfully several years with these physical

\* Lundy, born in San Francisco, Oct. 6, 1884, was U. Calif. Coll. Mines graduate (M.E., 1907). He was active in prospecting, estimating, and operating jobs throughout U. S. before coming to Big Hill in 1917. He came to Freeport's Hoskins Mound in 1920 to study samples and became supt. production here and at Bryanmound in 1923, gen. mgr. in 1930, vice-pres. in 1933.

handicaps, Lundy reported<sup>36</sup> with justified pride that greater thermal efficiencies were obtained at Hoskins than were ever achieved at Bryanmound, and the company was able to tell its shareholders that "production at Hoskins Mound is limited only by boiler capacity."<sup>37</sup>

Meanwhile the last drop of molten sulfur had been pumped from the Louisiana mine of the Union Sulphur Company. December 23, 1924, this historic operation closed, having brought to the surface 9,400,000 long tons of sulfur in twenty years, less five days.<sup>38</sup> The company sold out of stockpile until 1929,<sup>39</sup> while carrying on sulfur explorations financed by a special fund of \$20,000,000 set aside out of surplus.<sup>40</sup> Nine wells were drilled at Damon Mound\* and a small battery of boilers erected, but the Damon property was never really worked. Union moved ten miles to Big Creek where in 1925-26 six wells were steamed. A total production of only 1,070 tons of sulfur was achieved.<sup>41</sup> Though prospecting continued several years, this was the last actual sulfur venture of the Union Company which turned more and more to oil and gas and in 1940 became frankly and actively a petroleum company.<sup>42</sup>

The untoward experience of the Union Sulphur Company is the specter that haunts every sulfur company management. It admonishes that adequate reserves are essential. It warns that among all the long chances of mining there is no greater gamble than a sulfur dome. In the Gulf Coast region, more than 200 of these curious formations† have been located. Even where the sulfur horizon is extensive, there is no assurance that the underground formations will be suitable for the operation of the Frasch process, and there is no way of predetermining this vital information. If the deposit at Sulphur Mine, Louisiana, had not been rich and extensive, it is unlikely that even the resourceful perseverance of Herman Frasch would have been rewarded. Every dome steamed has proved to be a rule unto itself. Accordingly the efficiencies attained by his remarkable mining process vary almost infinitely from dome to dome, even from different sections of the same deposit.

During the twenties a new, smaller sulfur-mining company risked all these long odds, undertaking to develop the Palangana Dome after both

\* A romantic site, originally the stronghold of the Karankawa Indians, on whose sides are found the famous "sour dirt," used as medicine by the aborigines and now owned by the Vitalis Co. First settler was Samuel Damon, a blacksmith; first oil prospector, J. M. Guffey; backer of the sulfur development, Henry T. Staiti, who helped develop Bryanmound. For details, see Geo. M. Bevier, in Moore, ed., *Geology of Salt Dome Oil Fields*, p. 613; Haynes, *op. cit.* pp. 50, 200, 229.

† "In the Gulf Coast region 116 salt domes have been definitely proved by drilling. Of these not more than 75 or 80 are shallow enough or have sufficient caprock—the horizon containing sulfur, if any—to warrant even prospecting for that mineral." (Albert G. Wolf, to author, Mar. 11, 1946.) For contemporary accounts of sulfur developments, see R. F. Bacon and H. S. Davis, *Chem. Age* 23, 35 (1921); *Dun's Intern. Rev.* 39 (July 1928).

Texas Gulf and Union had rejected it. Like most Texas mounds, Palangana had a checkered past as a petroleum prospect. In 1920 its repeated indications of sulfur captured the attention of Edward F. Simms, a member of the original syndicate to develop Bryanmound. He gathered together a parcel of leases and drilled a test well.<sup>43</sup> Four years later J. W. Cain and A. H. Smith, oil lease traders from Houston, leased Simms' rights and drilled a wildcat which made a promising showing of sulfur. They interested two of the three sulfur-mining companies: Texas Gulf cored twenty-five test wells; Union Sulphur, four. A small sulfur body was plainly indicated, but the horizon appeared to be uneven and both companies released their rights. Undismayed by these experienced opinions, Cain and Smith secured control of Palangana and organized the Duval Texas Sulphur Company,\* capitalized at \$1,000,000, a quarter of the stock of which they took in exchange for the property.<sup>44</sup> The manager of this venture was George F. Zoffman, a Stanford-trained mining engineer with twenty years' mining experience in Mexico, who engaged as production superintendent August T. Drachenberg. This veteran of the days when Frasch was first experimenting with his process had uncanny skill as a sulfur-well operator. Duval worked Palangana from October 1928 to March 1935, raising 237,689 tons of sulfur.<sup>45</sup>

On the hint of a seepage of hydrogen sulfide gas discovered in 1922 on the banks of the San Bernard River, James F. Weed gathered up a group of oil leases in the neighborhood. During the next three years, several big oil companies worked this field, and their exploratory drillings sporadically turned up yellow sulfur cuttings. In the spring of 1927 two wells of the Gulf Production Company gave such striking evidence of sulfur that it clutched the attention of all three large sulfur companies. After spirited competitive negotiations, Texas Gulf Sulphur Company secured the sulfur rights for \$3,000,000 cash and half the profits less the cost of equipment, including prospecting, the reservoir, a townsite, and so forth.<sup>46</sup> The deal, which included an option on certain sulfur rights controlled by Gulf interests, proved to be an excellent bargain, for this Boling Dome materialized munificently, becoming the largest sulfur mine in the world.

The Boling deposit lies under a great block of land originally granted by Mexico to Stephen F. Austin, the American colonizer of the old Tejas State. Before the oil discovery, the tract had been subdivided by the Missouri Land Company which had sold eighty-acre farms to a number of different owners. The oil leases of most of these properties called for

\* Subsequently the Houston investment house of Moody, Seagraves & Co., prominent in developing oil and gas properties, secured a substantial financial interest in this enterprise. When their gas interests were sold in 1930, to the United Gas Corp., a subsidiary of Electric Bond & Share, this interest in Duval was included. (See Haynes, *op. cit.* p. 220.)

drilling within a five-year period and many of these were due to expire within three months after the notable sulfur showing. To protect these leases Gulf moved in 25 drilling rigs, and after Texas Gulf Sulphur took over the sulfur rights, 200 carefully planned development wells were cored and tested. This survey, which revealed the great extent of the sulfur horizon, was not completed until May 31, 1928.

Under Wilber Judson,\* vice-president in charge of production, construction was begun at once and production was aimed to start March 19, 1929, the tenth anniversary of the company's first production at Big Hill. Unlike most sulfur locations, Boling lay beneath a semitropical jungle. Every bag of cement, every two-by-four, thousands of feet of iron piping, all had to be dragged in four miles over narrow wagon roads that during the rainy season became canals of unadulterated Texas gumbo, rich as cream, sticky as molasses. The plans drawn by the company engineering staff in collaboration with the J. G. White Engineering Corporation, which had built the Big Hill plant in 1918, called for 8,000,000 gallons of superheated water every 24 hours.† Construction was completed so that steaming started the middle of March, but no well was sealed until a few hours after midnight of March 19, so that production actually began March 20, a day after the anniversary.<sup>47</sup>

By 1929, therefore, both Freeport and Texas Gulf had dispelled the bugaboo of depletion by putting second domes into production. Within the next few years the original operation of both—Freeport's Bryan-mound and Texas Gulf's Big Hill, or Old Gulf—were both discontinued.

During the early postwar years, when output exceeded domestic consumption and while Union was still in active production, all three companies attempted to ship as much sulfur as possible to Europe. The conference with the Sicilian Consortium at Geneva, August 1922, having failed to reach any agreement,‡ formation of a Sulphur Export Corporation under the Webb-Pomerene Act proved the key to this problem.<sup>48</sup> Organization was completed late in 1922, with all three American sulfur companies active members, the officers being Clarence A. Snider,

\* After a dozen years' field work in Mexico, So. Am., and the U. S., Judson, who had been trained at Harvard and Mich. Coll. Mines, became associated with Wm. Boyce Thompson and served between 1917-21 as officer and dir. of various mining companies. In 1921 he joined the executive staff of Texas Gulf Sulphur, becoming vice-pres. in 1926 and the next year taking general charge at Boling. A shrewd, patient, friendly man, he is a splendid negotiator and has represented his company in the purchase or lease of many sulfur properties and the Sulphur Export Corp. in agreements with the Sicilian industry. He had been dir., Am. Inst. Min. Met. Engrs., and vice-pres., Min. Met. Soc. Am. He was born in Lansing, Mich., July 26, 1880. (See also Vol. II, p. 214.)

† Water was drawn from the San Bernard River and from wells of surface water high in soda content suitable for the lime-soda softening process. (See Haynes, *op. cit.* p. 208.)

‡ See Vol. II, p. 217.

president; S. Magnus Swenson, vice-president; James T. Kilbreth, secretary; and Charles W. Kemmler, treasurer.<sup>49</sup>

The reopened negotiations got off to a bad start in New York. The Sicilian emissary, Guido Jung, former commercial attaché at the Italian embassy in Washington, was a tough-fibered trader, and he held out stoutly for the Mediterranean market, including the vineyards business of southern France and of Spain. The conference moved to London, later to Paris, and five months afterwards to Rome. Acting as a unit under government auspices, the Sicilians tried to play the old game of divide and rule which failed, thanks to Sulexco, as the Webb-Pomerene association was called. March 14, 1923, the agreement was formally signed.<sup>50</sup>

In this understanding it was unnecessary even to consider the Italian or the North American markets. By royal decree importation of sulfur into Italy had been banned. The American domestic price was lower than the export quotations, so Italian sulfur was as effectively barred here. Accordingly the agreement lived up rigorously to the Webb-Pomerene requirements prohibiting any commitments to allocate markets or control prices with the United States.\* A minimum of 135,000 tons was guaranteed Sicilian producers, after which the world markets (excluding Italy, North America, Cuba, and insular possessions of the United States) were divided on a basis of 75 to Sulexco, 25 to the Consortium. Minimum prices were to be mutually agreed upon from time to time, and a statistical office to compile correct data for pricing and allocation of markets was set up in London under A. Hughes.† As European sales representatives Sulexco appointed Pierre Chaubert, former representative of Freeport, and Charles E. Hope, manager of the Union refining plant at Marseilles.<sup>51</sup> By these means a world market, which had been depressed to a point that was ruinous to the Sicilian producers and which was costing the three American companies \$1,500,000 a year,<sup>52</sup> was stabilized upon a basis that enabled the Sicilian mines to operate at a profit.

While Gulf Coast brimstone was thus consolidating its position at home and abroad, unusual activity stirred in the inconspicuous but interesting production of sulfur in surface deposits in the Far West and in the by-product recovery of sulfur in this country. In Western sulfur,

\* In conformity with the law this agreement was filed with the Fed. Trade Comm.; in Italy, as a Govt. contract, its terms were not made public. It remained in force till late 1934, when the Fascist Govt. replaced the Consortium by the Ufficio per la Vendita dello Zolfo Italiano.

† Formerly associated with the English chemical merchants, Chance & Hunt, European agents of Texas Gulf. On his death in 1936, he was succeeded by his son, B. C. Hughes. The harmonious working of the Sulexco-Consortium agreement was largely due to the impartial, confidence-inspiring administration of these men.



which accounted for only some 4,000 tons yearly,<sup>53</sup> chiefly from California, two new producers appeared, the Western Sulphur Company, incorporated in San Francisco by William L. Holloway, F. C. Hutchens, and H. A. Judy, and the Humboldt Sulphur Company, of which Arthur J. Crowley was president.<sup>54</sup> The latter company obtained control in 1924 of what was said to be the second largest surface deposit in the United States at Battle Mountain, Nevada. After two years' development work, production began in 1926, and in 1929 capitalization was increased from \$1,000,000 to \$1,600,000. In the meantime the American Sulphur Company had taken over the property of the Death Valley Sulphur Company, Reno; and West Coast Chemical Company, backed by F. A. Somers and H. R. Bostwick, leased the plant of the Pacific Coast Shipbuilding Company at Bay Point, California, and installed sulfur-grinding machinery.<sup>55</sup>

Between 1924 and 1929 production of by-product sulfur from smelters increased from 203,000 to 243,000 long tons.\* Another source of sulfur developed between 1922 and 1929 from coal and fuel oils used to make coke, coke-oven gas, and miscellaneous fuel gases. Such sulfur compounds produce hydrogen sulfide in fuel gas, an impurity that necessitated more or less expensive removal. In 1922, the so-called iron oxide process was in practically universal use for this purpose, but a new process had just been developed by the Koppers Company, using a solution of sodium carbonate. In 1921 this process had been installed at the plant of its subsidiary, the Seaboard By-Product Coke Company at Kearny, New Jersey. It was very successful and in the next few years was adopted at about 50 plants. It proved to be the first step in the development of practical methods of recovering pure sulfur in salable form from the hydrogen sulfide contained in fuel gases.<sup>56</sup>

By 1925 two such processes, known to the trade as sulfur-recovery liquid purification processes, had appeared. Basically, however, both were variations of the method of using sodium carbonate solution to absorb hydrogen sulfide from the gas and regenerating the spent solution by oxidation with air with the formation of precipitated sulfur in the solution. These methods were developed by the engineers of three companies quite independently, the essential difference being in the oxidation catalyst used: iron oxide by the Koppers Company and the Standard Oil Development Company; nickel sulfide by the Pacific Gas & Electric Company.<sup>57</sup> Koppers undertook construction of equipment for both processes, and by the end of 1929 there had been 16 installations, including three small plants in France and the three built by the Pacific Gas & Electric Company for its own plants in California.

\* For U. S. sulfur consumption from chief sulfur-bearing materials, 1923-29, and its distribution in the chemical industry, see Appendix XVII.

Sulfur recovery by these processes was not considered satisfactory and after more research the Thylox process was developed. The efficiency of recovery and the quality of the recovered sulfur were improved, and by the end of 1929 Koppers had already made the first commercial installations. There were by this time 18 installations of the various sulfur-recovery processes in the United States and Canada with a capacity of around 18 tons of sulfur per day or 6,000 tons per year. The sulfur produced by these plants was a finely divided precipitated powder that did not immediately fit into any established part of the sulfur market. There were a number of suggested uses in agriculture, but no real tonnage sales until a prolonged series of tests initiated by E. R. de Ong at the University of California had demonstrated its value.<sup>58</sup>

Efforts directed toward the development of a similar liquid purification process to recover hydrogen sulfide as such from coke-oven gas had also been successful.\* This process was installed a few years later at the coke plant of the Pittsburgh Coke & Chemical Company, where the recovered hydrogen sulfide was used for the manufacture of their own sulfuric acid. Later refinements of this process have made it still more practical, offering coke plants the opportunity to become independent of outside sources of sulfuric acid for the preparation of ammonium sulfate.

In Canada, where some \$3,000,000 worth of brimstone was imported yearly for the pulp and paper industry, the National Research Council at Ottawa supported research at the University of Toronto by M. C. Boswell, who discovered a catalytic process of recovering sulfur dioxide from smelter fuels by organic means.<sup>59</sup>

As sulfur consumption mounted above war-year totals, the output of domestic pyrites struggled slowly back to approximately the prewar level † while imports reached only half the prewar totals.<sup>60</sup> Significant domestic developments were increasing ownership of pyrites properties by chemical companies and the use of pyrrhotite concentrates, which started in 1925 and by 1929 placed Tennessee ahead of Virginia as the leading producing state.<sup>61</sup>

The Tennessee Copper & Chemical Corporation, operating the largest single sulfuric acid plant in the country, continued its expansion, authorizing in 1926 the sale of \$3,000,000 worth of 6 per cent 15-year gold bonds, \$1,600,000 of which were offered to stockholders at par on October 1.<sup>62</sup> During the readjustment period, its neighbor, the pioneering, English-owned Ducktown Sulphur, Copper & Iron Company, Ltd., went into a receivership, but was reorganized by a group of Chattanooga and New York businessmen in 1925 as the Ducktown Chemical & Iron

\* F. W. Sperr, Jr., and R. E. Hall, U. S. Pat. 1,533,773 (1925), ass. to Koppers.

† For complete pyrites statistics, see Appendix XVIII.

Company. In 1927 it was acquired by the Copper Pyrites Corporation whose president, William Y. Westervelt, became its head with F. M. and A. P. Kirby directors. Although a new corporation, the Ducktown Pyrites Corporation, was formed, operations were continued in the old name, the Ducktown Chemical & Iron Company, and a concentrating mill similar to the one at the Mary Mine was installed at the Isabella Mine.<sup>63</sup> A mechanical roasting plant was also built through which iron concentrates were put for release of their sulfur to the adjacent sulfuric acid plant.<sup>64</sup>

At this time the Grasselli Chemical Company extended its pyrites holdings in Canada by purchase of the property of John Holdsworth at Hawk Junction, Ontario.<sup>65</sup> Except where mined by chemical companies, however, pyrites production in this country was tending more and more to become a by-product of copper or zinc mining operations, as for example the shipments from the Colorado zinc-lead mill to the Denver plant of the General Chemical Company, or from the Leona White Mine in California to the Stauffer Chemical Company.<sup>66</sup>

European pyrites producers, on the other hand, were endeavoring in the fashion of the times to weather the reconstruction storms by joining in a cartel. Although started in 1926 with a membership including not only Rio Tinto and Metallgesellschaft, but most of the smaller producers in Spain, Portugal, Cyprus, and Norway, this alliance was short-lived. Early in 1927 the predominant member, Rio Tinto, operating in Spain and owned in England, served notice that it would withdraw January 1928.<sup>67</sup> This strong firm desired to operate in the important American market with a free hand unhampered by the cartel agreement.

In March 1927, C. Wilbur Miller, president, and Allan Carter, a director of the Davison Chemical Company, returned the visit to this country of Sir Auckland Geddes, president of Rio Tinto. The following September Davison Chemical issued 90,000 shares of its common stock for 90,000 ordinary shares of the Pyrites Company, Ltd., a subsidiary of Rio Tinto Company. This transaction did not involve the transfer of the Cuban property,\* as stated in the trade press at the time, nor did Davison take over the refining operations of the English firm at Wilmington, Delaware. It did process cinders in its copper leaching and sintering plant at Curtis Bay, for account of Pyrites for several years. Davison also bought the sulfur content of pyrites ore from Pyrites over a long period of years until the beginning of World War II.<sup>68</sup> Lord Denbigh, a director of Rio Tinto, and A. D. Ledoux, a director

\* Owned now by the Davison Sulphur Co., subsidiary of the Davison Chemical Co., this property comprised some 3,280 acres on which pyrites reserves of an estimated 2,300,000 tons had been blocked out by Pope Yeatman. Davison spent more than \$5,000,000 in the purchase and development of these mines.

of Pyrites, joined the board of Davison.<sup>69</sup> This trade undoubtedly helped Rio Tinto. It did not materially improve the position of imported pyrites, which only reached half of prewar quantities.

## REFERENCES

1. R. F. Bacon and H. S. Davis, *Trans. Am. Inst. Chem. Engrs.* 13, Pt. 2, 1 (1920-21); R. W. Edmonds, *Mfrs. Rec.* 69 (July 10, 1924); W. A. Browne, *J. Geog.* 222 (Sept. 1931); E. R. Riegel, *Quart. J. Econ.* 4 (Feb. 1939). Basic sources on sulfur and sulfuric acid are: Fairlie, *Sulphuric Acid Manufacture*; Kreps, *Economics of Sulfuric Acid Industry*; Haynes, *Stone That Burns*.
2. D. B. Mason, *Ind. Eng. Chem.* 30, 746 (1938).
3. J. prakt. Chem. n. s. 51, 108 (1895); *Jahrb. Chem.* 9, 304 (1899); de Haën's basic pat. in this country is U. S. Pat. 687,834 (1913).
4. J. C. Olsen and H. Maisner, *Ind. Eng. Chem.* 29, 254 (1937).
5. Brit. Pat. 23,541 (1913); Ger. Pat. 291,792 (1914); Fairlie, *op. cit.* p. 410.
6. U. S. Pat. 1,371,004, reiss. Sept. 21, 1934.
7. U. S. Pats. 1,675,308-9 (1928); A. O. Jaeger, *Ind. Eng. Chem.* 21, 627 (1929).
8. Monsanto Chemical Works vs. A. O. Jaeger et. al., Equity No. 1892, U. S. Dist. Court West. Dist. Pa. (1929); *Ind. Eng. Chem., News Ed.* 3 (Feb. 10, 1929); *O.P.D. Repr.* 63 (Jan. 30, 1928). For vanadium catalyst development, see also L. F. Nickell, *Chem. Met. Eng.* 35, 153 (1928); S. F. Spangler, *Ind. Eng. Chem.* 21, 417 (1929); B. D. Saklatwalla, Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 7, 1929, p. 33; Rogers' *Industrial Chemistry*, 5th ed., I, 163; Fairlie, *op. cit.* p. 398; Kreps, *op. cit.* p. 54.
9. General Chemical Co. vs. Selden Co., Equity No. 2358, U. S. Dist. Court West. Dist. Pa., II, 731 (1932); *Ind. Eng. Chem., News Ed.* 10, 179 (1932); Fairlie, *op. cit.* p. 408.
10. *Metallbörse* 1633, 1913, 2305, 2473, 2805 (1929); see also Lunge, *Handbuch der Schwefelsäurefabrikation*, III, 1546, 1729, 1758 (1930).
11. Nickell, *op. cit.*; Spangler, *op. cit.*; *O.P.D. Repr.* 63 (Jan. 30, 1928).
12. Fairlie, *op. cit.* p. 392.
13. Patrick, U. S. Pat. 1,297,294 (1919); other U. S. Pats. on platinized silica gel, 1,547,236; 1,577,188; 1,683,694; 1,695,740; 1,782,857; H. N. Holmes, J. Ramsey, and A. L. Elder, *Ind. Eng. Chem.* 21, 850 (1929); M. C. Roop, to author, Mar. 28, 1946.
14. *Chem. Mkts.* 21, 571 (1927).
15. *Ibid.* 24, 281 (1929); 26, 140 (1930).
16. T. R. Olive, *Chem. Met. Eng.* 36, 614 (1929).
17. C. S. Imison and W. Russell, *J. Soc. Chem. Ind.* 41, 37T (1922); L. A. Pratt, *Survey of American Chemistry (1925-26)*, I, 68; G. B. Taylor, *Ind. Eng. Chem.* 19, 1252 (1927); D. H. Killeffer, *ibid.* 1153; Spangler, *op. cit.*
18. *Min. & Met.* 5, 187 (1924); *Min. Ind.* 1923, 646.
19. Fairlie, *op. cit.* p. 192; *Ibid.*, *Chem. Met. Eng.* 44, 32 (1937); *Ind. Eng. Chem.* 19, 644 (1927).
20. *Chem. Mkts.* 21, 645, 859 (1927).
21. *O.P.D. Repr.* 57 (Dec. 17, 1928); *Drug Chem. Mkts.* 10, 396 (1922), 19, 27 (1926).
22. Co. memo to author.
23. *Ibid.*
24. *Chem. Met. Eng.* 34, 655 (1927).
25. *Chem. Mkts.* 20, 549, 649 (1927); 23, 163 (1928).
26. *Drug Chem. Mkts.* 14, 10 (1922).
27. *Engineer* 134, 96 (1922); Fairlie, *op. cit.* pp. 576-91.
28. W. W. Duecker, to author, Mar. 10, 1946.
29. Union Sulphur Co. vs. Freeport Sulphur Co., Equity No. 336, U. S. Dist. Court Del. (1915); Nos. 2391-2, U. S. Circuit Court of Appeals, 3rd Circuit (Oct. term, 1918).
30. *Min. Res.* 1919, II, 536; *Min. Ind.* 1918, 667, 1919, 642, 1921, 642.
31. Haynes, *op. cit.* p. 200.
32. *Min. Res.* 1928, II, 58.
33. Haynes, *op. cit.* p. 186.

34. *Ibid.* p. 187.
35. Freeport Texas Co., *Ann. Rept.* 1923, p. 4; *Min. Ind.* 1923, 632; *Drug Chem. Mkts.* 12, 505 (1923).
36. Lundy, *Report on Estimated Ore Reserves at Hoskins Mound*, Jan. 18, 1927, p. 10 (unpublished).
37. Freeport Texas Co., *Ann. Rept.* 1928, p. 1.
38. Haynes, *op. cit.* p. 315; *Min. Ind.* 1924, 664; *Pharm. Era* 60, 20 (1925).
39. Co. memo to author.
40. *Chem. Mkts.* 19, 18 (1926).
41. Haynes, *op. cit.* p. 202.
42. Co. memo to author.
43. R. E. Moore, ed., *Geology of Salt Dome Oil Fields*, chap. by D. C. Barton, pp. 718-71.
44. *Chem. Mkts.* 19, 776 (1926).
45. Haynes, *Chem. Ind.* 34, 499 (1934); *ibid.*, *Stone That Burns*, p. 315.
46. *Ibid.*, *Stone That Burns*, p. 204.
47. *Ibid.* p. 208.
48. *Min. Ind.* 1923, 632.
49. *Drug Chem. Mkts.* 12, 17 (1923).
50. *Ibid.* 403; Haynes, *Stone That Burns*, p. 176.
51. Haynes, *Stone That Burns*, p. 178.
52. *Wall St. J.* quoted, *Drug Chem. Mkts.* 14, 1536 (1924).
53. Kreps, *op. cit.* p. 101.
54. *Drug Chem. Mkts.* 18, 1078 (1926); *Chem. Mkts.* 21, 184 (1927), 24, 189 (1929).
55. *Drug Chem. Mkts.* 12, 1043 (1925); *Chem. Mkts.* 20, 797 (1927).
56. H. A. Gollmar, to author, Mar. 21, 1946; *Chem. Met. Eng.* 34, 453 (1927); *Chem. Mkts.* 24, 267 (1929).
57. Koppers Co. memo to author; F. W. Sperr, Jr., *Proc. 2d Intern. Conf. Bituminous Coal* 2, 37 (1928); K. N. Cundall, *Chem. Met. Eng.* 34, 143 (1927).
58. *Chem. Mkts.* 19, 1027 (1928). See also E. R. de Ong and M. Huntoon, *J. Econ. Entomol.* 22, 866 (1929); H. W. Anderson, *Trans. Ill. Hort. Soc.* 1929, p. 117; R. C. Williams and H. C. Young, *Ind. Eng. Chem.* 21, 359 (1929); J. M. Hamilton, N. Y. Agr. Exp. Sta., *Bull. No. 604* (1932); Duecker and E. W. Fddy, *Chem. Ind.* 50, 179 (1942).
59. *Chem. Mkts.* 25, 30 (1929); Boswell and G. P. Beal, *Can. Pat.* 355,155 (1933).
60. Kreps, *op. cit.* p. 98; G. J. Young, *Eng. Min. J.* 113, 573 (1922).
61. *Min. Res.* 1929, II, 189.
62. *Chem. Mkts.* 19, 498, 694 (1926).
63. *Ibid.* 20, 648, 746 (1927); *Min. Res.* 1925, I, 359.
64. *Chem. Ind.* 38, 81 (May 1935).
65. *Chem. Mkts.* 19, 663 (1926).
66. Kreps, *op. cit.* p. 99.
67. *Chem. Mkts.* 20, 121, 481, 829 (1927).
68. Roop, *op. cit.*
69. Edmonds, *Mfrs. Rec.* 71 (July 5, 1928); *Chem. Mkts.* 21, 501, 571 (1927).

## Chapter 6

### NITRIC ACID FROM AMMONIA

SYNTHETIC VS. BY-PRODUCT AMMONIA COMPETITION HALVES PRICE, BENEFITING ALL CONSUMING INDUSTRIES—ATMOSPHERIC NITROGEN BUILDS LARGEST AMERICAN AIR-NITROGEN PLANT—DU PONT BUYS AMERICAN RIGHTS TO CLAUDE AND CASALE PROCESSES, ORGANIZES LAZOTE—SHELL ON WEST COAST WORKS MONT CENIS PROCESS—NITROGEN ENGINEERING BUILDS PLANTS ABROAD—WIDESPREAD AMERICAN ADOPTION OF OSTWALD PROCESS FOR NITRIC ACID, WITH IMPROVEMENTS IN CATALYSTS, GASES, AND APPARATUS.

SEPTEMBER 28, 1925, synthetic ammonia staged, as the artists say, a "one-man show," a startling, unmistakable demonstration of the impact of technical progress upon processes, products, and prices in the chemical industry. That day the Mathieson Alkali Works, a newcomer in the ammonia market, operating at Niagara Falls a synthetic ammonia plant designed and built by American-trained chemical engineers, captured a generous slice of the refrigeration business of one of the big packing houses on the basis of a lower price. Distributors of by-product ammonia, recovered from the crude liquors of the gas and steel industries' coking plants, immediately cut their quotations deeply. Synthetic producers slashed back. Within a week the price of anhydrous ammonia had been reduced from 30 cents to 16½ cents. By the end of the year it had been further lowered to 15 cents.

This sharp price reduction brought almost immediately a decline by half in the price of ammonia water and markedly lower prices for such important derivatives as the carbonate, the chloride, and the acetate. But the effects did not stop at direct price repercussions. Nitrogen from the air had become a commercial reality in this country, a factor to be reckoned with in plant and market place.<sup>1</sup>

Cheaper ammonia stimulated the whole field of refrigeration. It touched fertilizers by lowering the cost of ammonium sulfate, by introducing ammonia, ammonium nitrate, and urea as nitrogen-bearing plant-food components, and by setting up effective competition against Chilean saltpeter. Nor did chemical techniques escape, for cheaper ammonia soon largely replaced sodium nitrate in the chamber process for sulfuric acid and it completely revolutionized the manufacture of nitric acid.\* That drastic price reduction was literally our declaration of nitrogen independence.

\* For production and distribution of ammonia products, see Appendix XIX.

This was a notable revival from the doldrums into which the whole national synthetic nitrogen program had slumped at the close of the war.\* Shutdown of the government-built ammonia and cyanamide plants at Muscle Shoals in 1919 had left only the small arc process of the American Nitrogen Products Company at La Grande, Washington, and the still experimental synthetic ammonia plant of the Atmospheric Nitrogen Corporation at Syracuse, New York, in actual operation.†

The West Coast arc operation, which never exceeded an annual delivery of 300 metric tons of nitrogen fixed in the form of sodium nitrite, continued on this modest scale until May 1927,<sup>2</sup> when fire gutted the installation with a loss of \$300,000.<sup>3</sup> The management announced that owing to the uncertainty of its future power supply, the plant would not be rebuilt and the company would be dissolved.<sup>4</sup> This was a face-saving statement. The high power requirements of the arc process, which eventually caused its abandonment even in the pioneer Norwegian plants, made that historic Pacific Coast operation uneconomic.<sup>5</sup>

The Atmospheric Nitrogen Corporation project, on the other hand, grew to be the largest single American producer during the twenties. From it the greatest air-nitrogen plant in North America sprang at Hopewell, Virginia. Organized in 1919 to follow through the work initiated by Dr. William H. Nichols to adapt the Haber process, which had led to the government contract with General Chemical to build the synthetic ammonia plant at Muscle Shoals, this Allied Chemical & Dye subsidiary brought its Syracuse plant into commercial production in 1921. It had first been intended to use sodium amide, but this was changed to the de Jahn ‡ catalyst,<sup>6</sup> and later to Larson's iron oxide catalysts. This Syracuse plant quickly became the largest domestic producer of synthetic ammonia, and early in 1927 Allied Chemical & Dye decided further to capitalize the know-how and market position won by Atmospheric Nitrogen. Up to this time research and development had cost between \$4,500,000 and \$5,000,000.<sup>7</sup> A further investment of \$125,000,000 § was made in a new air-nitrogen plant at Hope-

\* For contemporary reviews of the technical and commercial development of this period, see R. S. Tour, *Trans. Am. Inst. Chem. Engrs.* 20, 213 (1927); F. A. Ernst, *Trans. Am. Electrochem. Soc.* 51, 251 (1927); W. S. Landis, *Ind. Eng. Chem.* 20, 1145 (1928); J. E. Crane, *ibid.* 1128; E. M. Allen, *ibid.* 1131; L. C. Jones, *Chem. Mkts.* 24, 245 (1929).

† See Vol. II, p. 122.

‡ Frederick W. de Jahn made this discovery in Dec. 1919, about the time Atmospheric Nitrogen was formed. The invention was reduced to practice Aug. 10, 1921, and patent applied for May 12, 1923. Priority of invention was awarded to de Jahn in a suit brought by J. C. Clancy in the Court of Customs & Patent Appeals, Dec. 19, 1929, and 2 yrs. later, U. S. Pat. 1,815,243 iss. to him. (See *Off. Gaz.* 244, Mar. 11, 1930; *O.P.D. Reprtr.* 21, Dec. 30, 1929.)

§ This figure, published currently in *Chem. Mkts.*, has been questioned by several readers of this chapter. Chas. O. Brown wrote: "Investment at Hopewell seems very high—about \$26,000,000 for total ammonia plant plus \$16,000,000 for sodium nitrate

well.<sup>8</sup> A tract of 278 acres was purchased from the Tubize Artificial Silk Company and a contract let to the Virginia Electric & Power Company for a steam-generating electrical plant to cost \$8,500,000.<sup>9</sup> During the closing days of November 1928, the first shipment of anhydrous ammonia left the new plant; December 4, a carload moved from Hopewell to the F. S. Royster Guano Company at Norfolk; a month later the initial shipment was made of synthetic sodium nitrate. This product became a feature of the production at Hopewell. Branded as "Arcadian sodium nitrate," sales were placed in the hands of the Barrett Company.<sup>10</sup>

Commercial production of synthetic ammonia at Syracuse in 1921 was promptly followed the next year by the Mathieson Alkali Works at Niagara Falls. Utilizing hydrogen produced in its electrolytic chlorine cells, nitrogen was fixed by the so-called American process developed by the Fixed Nitrogen Research Laboratory,<sup>11</sup> employing the iron oxide catalyst, sensitized with potassium oxide and alumina, that had been discovered by Dr. Alfred T. Larson.\* This process was soon abandoned for that of the Nitrogen Engineering Corporation and the native iron ore catalyst of Charles O. Brown.<sup>12</sup>

In 1924, a crucial year in synthetic ammonia, the Niagara Ammonia Company put on line, April 15, a Casale plant at Niagara Falls, producing eight and one-quarter tons a day. The Ammonia Corporation of New York had secured rights to the Casale process and organized this subsidiary which operated on by-product hydrogen from the adjacent plant of the Hooker Electrochemical Company.<sup>13</sup>

During this eventful year, du Pont secured American rights to the Claude process. It formed the subsidiary, Lazote, Inc.,<sup>14</sup> and purchased a site near Clinchfield, Virginia, which was later discarded for the land and plant of the Charleston Chemical Company at Belle, near Charleston, West Virginia.<sup>15</sup> Under superintendence of C. L. E. Cheetham, with Dr. R. M. Evans in charge of production, F. D. Snyder, ammonia superintendent, and W. H. Holstein, hydrogen superintendent,<sup>16</sup> this plant started production in February 1926.<sup>17</sup> Here processes were subsequently developed for the manufacture of urea, methanol, ethylene glycol, and other higher alcohols, and eventually for nylon intermediates and the methyl methacrylate resin Lucite. During the first ten years, before the accumulated yearly net operating results showed a dollars-and-cents profit, the company spent more than \$24,000,000 on the synthetic ammonia operations alone.<sup>18</sup>

facilities." (Memo to author, Mar. 30, 1946). This estimate of \$42,000,000 is confirmed by the "property account" in Allied's annual report for 1927, \$173,500,000; for 1931, \$223,100,000, an increase (undoubtedly not wholly the Hopewell plant) of \$49,600,000.

\* U. S. Pats. 1,489,497 (1924) and 1,554,008 (1925); see also Larson and C. N. Richardson, *Ind. Eng. Chem.* 17, 971 (1925).



In 1926 Lazote, Inc., was absorbed by the du Pont National Ammonia Company, organized with a capital of \$13,100,000 as a holding company for the joint interests of the E. I. du Pont de Nemours & Company and the National Ammonia Company, in all ammonia projects.<sup>19</sup> This same year Lazote sued the Ammonia Corporation and its subsidiary, the Niagara Ammonia Company, in the federal court at Buffalo for infringement of three patents. Although Lazote was operating the Claude and Niagara Ammonia the Casale process, it was claimed that the operating pressures infringed the Claude rights.<sup>20</sup> An injunction and accounting for damages were asked and two years later, as an outcome of this suit, F. S. MacGregor, president of both defendant companies,\* filed a voluntary petition in bankruptcy.<sup>21</sup> In 1927 the du Ponts, who already had exclusive American rights to the Claude process, bought American patent rights to the Casale process from the Ammonia Casale Société Anonyme de Basle and the Electric Bond & Share Company.<sup>22</sup> At Belle du Pont engineers had already introduced a number of modifications in the Claude process and later variations of the Casale † process were also adopted. In 1929, when du Pont bought out its associates in the ammonia project, the Lazote and National Ammonia names were dropped and the du Pont Ammonia Corporation formed.<sup>23</sup>

While Atmospheric Nitrogen and du Pont soon won the top places in output, a number of other synthetic ammonia producers launched forth during this period. In 1925 the Pacific Nitrogen Corporation, subsidiary of National Ammonia, started operations at Seattle, Washington,† and Roessler & Hasslacher opened a three-ton capacity plant at Niagara Falls.<sup>24</sup> In 1926 the Commercial Solvents Corporation built two new plants at Peoria, one of which was a synthetic ammonia operation designed and erected by the Nitrogen Engineering Corporation, utilizing waste hydrogen evolved in the fermentation of corn to butyl alcohol and acetone.<sup>25</sup>

During 1925 an insignificant output of fixed nitrogen in the form of sodium cyanide, along with very modest quantities of hydrocyanic acid,

\* Principal creditor of Niagara Ammonia (liab. \$947,748; assets \$107,899) was the Ammonia Corp. (liab. \$839,249; assets \$489,467) whose largest creditor was Lazote. (See *O.P.D. Rept.* 20, Feb. 20, 1928.)

† The inventor, Dr. Luigi Casale, died near Milan, Feb. 18, 1927, shortly before the American rights were acquired by du Pont.

‡ "My recollection is that design for a plant using 'the American process' was developed by F. A. Ernst and his assistants at the Fixed Nitrogen Research Lab. As the designs were nearing completion, young Dannenbaum, then with National Ammonia, now with du Pont (and not so young) spent a good deal of time at the F.N.R.L. The National Ammonia Co. then took the designs, borrowed Charlie Young from the F.N.R.L. and sent him to Seattle to supervise the construction and later the operation of the plant as designed by the F.N.R.L. and National Ammonia. After du Pont swallowed National Ammonia, the Seattle plant was shut down. About 1934 it was, I believe, dismantled and shipped to China." (H. A. Curtis, to author, Mar. 20, 1946.)

was achieved by the California Cyanide Company at Cudahy.<sup>26</sup> Geographically this project made good sense. There was a substantial market for sodium cyanide for the recovery of gold and silver in the Western mines and hydrocyanic acid was used in California citrus orchards as a fumigant. Nevertheless, although cyanide may be readily converted to ammonia, costs proved to be out of line with both the synthetic ammonia and the cyanamide processes.

Another unusual, exceedingly potential West Coast development was the entrance of a petroleum company into chemicals by the organization of the Shell Chemical Company. In 1929 this \$2,000,000 subsidiary of the Shell Union Oil Corporation and the Royal Dutch Petroleum Company was set up to make and market new chemicals uncovered in the laboratories of the Shell Development Company.<sup>27</sup> This nitrogen-fixation plant at Long Beach, California, cracked natural gas from the near-by oil fields and the hydrogen evolved was purified and employed in the synthesis of ammonia.<sup>28</sup> A new synthetic ammonia process, the Mont Cenis, was brought from Europe by Shell for this project.<sup>29</sup> It is distinguished by low operating pressure of 100 atmospheres and the extreme activity of its iron cyanide catalyst. As in the Nitrogen Engineering Corporation process, the ammonia recovered is in liquid form.

In 1927 a small, West Coast synthetic ammonia plant, using electrolytic by-product hydrogen as raw material, was installed by the Great Western Electro-Chemical Company at Pittsburg, California, under the direction of C. W. Schedler, vice-president in charge of production. This plant was scheduled for production of one ton of ammonia per day.<sup>30</sup>

In this country cut-and-try experimentation continued with operating conditions, especially the purification of the gases, the catalysts, and the operating pressures and converter systems. Progress in the practical technique was rapid.\* A novel method for the production of hydrogen was worked out by the Phosphorus-Hydrogen Company at Niagara Falls. It depended on production of elemental phosphorus in an electric furnace and steaming this in the presence of a catalyst to yield hydrogen and phosphoric acid. It has never been used commercially.<sup>31</sup>

American chemical engineers were beginning to assert enterprising originality in handling the extraordinary pressures and temperatures of

\* About the time the Mathieson plant came into production, the president, E. M. Allen, said to me, "Synthetic ammonia is a perfect instance of the terrific rate of technical obsolescence in the chemical business. It has been true the last three years, and I dare say it will be true for the next ten, that every nitrogen-fixation plant built all over the world is out-of-date before it is in operation." (W. H.)

"Eddie Allen's prediction was in error. The plant I built for him in 1925 is not only running today, but it is as efficient as any process he could get." (Chas. O. Brown, to author, Mar. 30, 1946.)

this new type of chemical process. They made notable improvements in apparatus designed for large-scale production. Every operating staff had a share in these developments, and the excellent work of the Fixed Nitrogen Research Laboratory, which was set up by the Army Ordnance Department during the war and afterwards transferred to the Department of Agriculture, continued after President Coolidge asked and received from Congress an additional appropriation of \$185,000.<sup>32</sup> Foreign recognition of American ability in this new field came when the Norwegians authorized the Nitrogen Engineering Corporation to replace their arc plant and was confirmed in 1928 when the famous French Etablissements Kuhlmann awarded the same firm a contract for a synthetic ammonia plant near Paris.<sup>33</sup> Thereafter "N.E.C." whose original incorporators were Louis C. Jones,\* president, and Charles C. Brown, treasurer,† began building a whole series of synthetic ammonia plants from Russia to the Far East. Indirectly this country had a hand in the development of the air-nitrogen industry of Japan, for in 1920 Fusansbu Isobe, a chemistry graduate from Indiana University in 1909, purchased for \$1,250,000 the Japanese and Chinese rights to the Claude process. In 1923 he erected a \$900,000 plant at Mikoshma and in 1930 a much larger operation, costing \$2,200,000, at Miike.<sup>34</sup>

In the domestic domain the first head-on impact of these fast-moving synthetic ammonia developments hit by-product ammonia. The blow fell in the autumn of 1925, when next year's contracts were being written by anhydrous ammonia's greatest bulk consumers. This was almost inevitable. At the time the chief producers of synthetic ammonia in the East, Atmospheric Nitrogen, Niagara Ammonia, and Mathieson sold their anhydrous ammonia direct, since neither had as yet worked up any employment of the material in their own chemical processing. The precipitous price drop was inspired by sales strategy in anticipation of still larger supplies from prospective producers: Allied Dye & Chemical plans for the new, much larger plant at Hopewell and the Claude process plant projected by du Pont at Belle.

The 50 per cent price decline in ammonia was promptly translated into lower quotations for ammonium salts. During 1926 cheaper ammonia came into active competition with sodium nitrate in the production of sulfuric and nitric acids. The following year the chief of the

\* See Vol. III, p. 46.

† Brown, like Jones, went with Nitrogen Engineering to the Chemical Construction Corp., organized in 1929 when taken over as an affiliate of American Cyanamid. Brown was born at Lakeport, N. H., Nov. 21, 1888, and educated at New Hampshire, Cornell, and Pittsburgh. The years 1913-23 saw him a fellow at Mellon Inst.; dir. plant lab. of Semet-Solvay; a Lt. Col. in Ordn. Dept. during the war; and in private consulting practice at Providence. Since resigning from Chemical Construction in 1935, Brown has again engaged in consulting work in N. Y. and is a contributing ed., *Ind. Eng. Chem.* He has an hon. D.Eng. from New Hampshire U.

fixed-nitrogen work of the Department of Agriculture, F. G. Cottrell, told the National Fertilizer Association at its meeting at Old Point Comfort that fixation of atmospheric nitrogen had reached a point which cut the dominance of Chilean nitrate in world markets and would oblige Chilean producers to adjust their plants and production schedules and sales policies to conform with these resultant competitive situations.<sup>85</sup>

The headlong fall in the price of ammonia overthrew the natural conservatism of heavy chemical makers, and the outstanding event of 1926 in the industry was the widespread installation of the ammonia-oxidation process in the production of nitric acid.<sup>86</sup> Although the oxidation of  $\text{NH}_3$  to  $\text{NO}$  had been observed toward the end of the eighteenth century, and as early as 1839 Kuhlmann had suggested platinum as a catalyst to induce this reaction, no industrial use had been made of this method until just before World War I. About 1902 Wilhelm Ostwald worked out a commercial process \* which theoretically operated at the high conversion efficiency of 95 per cent of ammonia to nitric oxide, but which was not feasible industrially because of the high cost of by-product coke-oven nitrogen and its impurities which poison the platinum catalyst. As has been repeatedly pointed out, pure, low-cost ammonia from the Haber process made the Ostwald process practical, and Germany did not risk a general European war until these two processes assured her independence of Chilean nitrate supplies from which she reasonably expected to be cut off by a British naval blockade.† Munitions demands necessitated a large-scale production of nitric acid, and Germany came out of the war self-sufficient in nitric acid. Her Continental neighbors and rivals, following her example, quickly adopted the Ostwald process.

Neither the United States nor Great Britain was ever wholly cut off from Chilean nitrate during the conflict, so the nitrogen-fixation pro-

\* The reactions involved are relatively simple. Ammonia gas and an excess of air are passed through a red-hot platinum gauze: (1)  $4\text{NH}_3 + 5\text{O}_2 = 4\text{NO} + 6\text{H}_2\text{O}$ . About 5% of the  $\text{NH}_3$  breaks down to form free  $\text{N}$  and all the  $\text{H}$  is converted to water vapor: (2)  $4\text{NH}_3 + 3\text{O}_2 = 2\text{N}_2 + 6\text{H}_2\text{O}$ . The gas mixture is cooled and  $\text{NO}$  combines with excess  $\text{O}$  spontaneously: (3)  $2\text{NO} + \text{O}_2 = 2\text{NO}_2$ . Countercurrent absorption of nitrogen peroxide into water is the final step: (4)  $3\text{NO}_2 + \text{H}_2\text{O} \rightleftharpoons 2\text{HNO}_3 + \text{NO}$ . The  $\text{NO}$  formed in (4) repeats reaction (3) which is again followed by the final conversion (4) until over 95% of the  $\text{NO}$  is converted to  $\text{HNO}_3$ .

† "I have seen this statement made several times, but have never seen supporting data. Germany expected a short war in 1914 and had stockpiled Chilean nitrate. She had only one relatively small synthetic ammonia plant, that at Oppau, in operation for about a year." (H. A. Curtis, *op. cit.*)

"These processes assured Germany independence from Norwegian as well as Chilean nitrate. Germany had sold out her interests in the Norwegian arc industry to the British about 1912 and used the proceeds to provide enlargement of the Haber process in preparation for World War I." (E. A. Rykenboer, to author, Mar. 29, 1946.)

gram lagged. It was therefore several years before synthetic ammonia became sufficiently plentiful and cheap to warrant general application of the ammonia-oxidation process. During the war, Dr. Walter S. Landis overcame numerous problems in untried techniques when he adapted ammonia oxidation to plant-scale operation at the Ammo-Phos plant of the American Cyanamid Company, Warners, New Jersey.\* Although the process worked on by-product ammonia, imperative demands on this material for fertilizers and for refrigeration prevented anything like full-scale operation † either in the American Cyanamid plant or a similar installation of the du Ponts.<sup>37</sup>

After the close of the war, an abortive attempt to adopt a direct air-oxidation method in this country was made in 1923 by the American Nitrogen Products Company, which was operating the arc process for production of sodium nitrite. A stream of electric sparks was passed through a current of moist air, with the formation of nitric acid.<sup>38</sup> Although off-peak power from the British Columbia Electric Railway Company plant at Lake Buntzen was used, this process, like its companion, proved impractical because of expensive power demands.

Early installations of the ammonia-oxidation system naturally ran into some harrying snags. An early trouble was the corrosion of the nitric acid converters. This was corrected by use of chrome steel, an application which led to fruitful studies of the physical durability and the chemical properties of this alloy.<sup>39</sup> The Ostwald process works either at atmospheric or elevated pressures, the latter being desirable because of the greater strength of the acid produced. A pressure of 100 pounds per square inch—a development in which du Pont played an important part—has been generally adopted in this country.<sup>40</sup> More economical conversion of peroxide to acid may be achieved by replacing part of the air by oxygen. Use of oxygen has reached a point where the ammonia is 11.2 per cent of the mixture in place of 9-10 per cent, but it is a difficult operation and as it is impossible to get back the cost of pure oxygen this practice is no longer attempted in American plants.<sup>41</sup>

Ostwald's original platinum catalyst and the base metal compounds

\* See Vol. II, p. 83.

† "The Landis oxidizer failed for more profound reasons. It was very small and would only run if the gauge was electrically heated, and the electrical circuits and controls were extensive and expensive. Equally important as the design of Landis was the Jones-Parsons converter, which Curtis has said was a headache. Maybe so, but it was making nitric acid at Split Rock in commercial quantities with good efficiency before we entered the First World War and has been used in other applications since. In the early days Harry Curtis did some valuable work on this process, as did Capt. Geo. Perley, now at Leeds & Northrup Co., Phila. As a designer of these early plants Walter W. Knistern was ten years before the du Ponts and Ralph S. Richardson, too, was a real pioneer; both able engineers who made real history in the development of high-pressure synthetic ammonia." (Chas. O. Brown, *op. cit.*)

adopted in Germany as a war makeshift, were both largely replaced by an American discovery,\* the platinum-rhodium catalyst. Another catalyst improvement, the multi-layer gauze with ten to thirty sheets per pad, was also developed in the United States,<sup>42</sup> where it was used by Jones and Parsons in the Semet-Solvay plant at Split Rock, near Syracuse, as early as 1917; installed at Muscle Shoals in 1918; and promptly adopted by the Belgians.<sup>43</sup> These men also perfected the first successful American-type converter, in 1916, using it at both the Semet-Solvay and Muscle Shoals plants during the war.† This has been largely superseded by apparatus aimed to speed conversion for large-scale production.

Another phase of the commercial production of synthetic ammonia receiving particular attention from American chemical engineers was the source and purification of the hydrogen gas. Such installations frequently utilize by-product hydrogen, as from the electrolytic chlorine cells at the alkali plant of Mathieson or the butyl alcohol fermentation at Commercial Solvents. In certain favored localities, natural gas proves to be a most economical source of hydrogen. It is prepared from methane by the patented ‡ thermitomic cracking or the passing of natural gas through a bed of red-hot coke in a water-gas generator; or the catalytic, high-temperature process wherein natural gas is passed over aluminum oxide and iron oxide catalysts in chromium-nickel tubes.<sup>44</sup> Many American producers consider the water-gas and producer gas reactions on coke or from natural gas as the cheapest sources of both hydrogen and nitrogen.<sup>45</sup>

Semet-Solvay, American Cyanamid, and du Pont were all trail breakers in commercial adoption of ammonia-oxidation processes. Semet-Solvay followed the pioneering Split Rock plant by a similar Jones-Parsons installation at the Canal Department in 1920. By taking over the important Nitrogen Engineering organization, American Cyanamid not only acquired two outstanding engineers, Louis Jones and Charles Brown, but it also became both operator and builder of synthetic ammonia and synthetic nitric acid plants. Considering du Pont's keen interest and long experience in nitric acid as an ingredient of explosives, and remembering its large investment in nitrate-mining properties in Chile, an acid test of synthetic nitric acid's success came in 1928 when oxidation units were installed in powder plants at Mineral Springs, Alabama; Repauno, New Jersey; and Barksdale, Wisconsin.<sup>46</sup> As might be expected from its close connection with Solvay's Atmospheric Nitrogen

\* C. W. Davis, U. S. Pats. 1,706,055 (1929), 1,850,316 (1932), ass. to du Pont.

† "The Jones-Parsons oxidizers were used only at U. S. Nitrate Plant No. 1 and were a headache. At U. S. Nitrate Plant No. 2 electrically heated gauzes (they were referred to as Landis oxidizers) were used." (H. A. Curtis, *op. cit.*)

‡ W. W. Odell, U. S. Pat. 1,762,100 (1930), ass. to Columbia Engineering & Management Corp.

Corporation, the General Chemical Company also early adopted the synthetic process, building an ammonia-oxidation unit at the Buffalo plant in 1928.<sup>47</sup>

From this time forward, practically all nitric acid installations followed one of the various modifications of the Ostwald system. While the old sodium nitrate operations were not immediately scrapped, the process accounted for a rapidly diminishing share of the national output. This grew rapidly during the twenties, when production of nitric acid increased more than 50 per cent.\* In 1929 a total of 143,154 short tons (basis 100 per cent acid) from 48 plants, with 97.9 per cent of this output going to chemical industries.†

A corollary of the rapidly growing importance of nitric acid in chemical processing is that the first tankcar to handle this active material built in the United States appeared in 1928.<sup>48</sup> It was shipped in November by the Combustion Engineering Corporation through its affiliate, Hedges-Walsh-Weidner Company, and was thirty-one feet, nine inches long, with an inside diameter of six feet, one and one-half inches, a demonstration of the increasing demands for nitric acid and of the improving technique of tankcar construction.

More efficient methods of handling this refractory acid in aluminum-lined drums had quite an unexpected effect. It made possible the importation of nitric acid of greater than 50 per cent strength, an opportunity that European makers did not overlook. Accordingly, in 1929, the Tariff Commission was petitioned for a 1 cent a pound duty, and at the hearings of the Ways and Means Committee,<sup>49</sup> the testimony of Colonel William S. Weeks‡ of Calco emphasized this container aspect of the competitive situation. He pointed out that the younger industry in this country would need three years at least in which to iron out certain expected and unavoidable difficulties in the operation of a new process and to adjust conflicting patent claims, before it would be able to meet squarely the competition of the European producers. When the new tariff came to be written, however, nitric acid continued on the free list.

\* For statistics of nitric acid production, 1923-29, see Appendix XX.

† As estimated in 1927, of a total domestic consumption of 153,000 short tons of  $\text{HNO}_3$  (basis 36° Bé), the largest part— $\frac{2}{3}$  or some 107,000 tons—went into industrial explosives, followed by heavy chemicals, 15,000; paint & varnish, 16,000; dyes & other coal-tar products, 5,000; rayon & other textiles, 3,000; fine chemicals & drugs, 2,500; fertilizers & insecticides, 900; electrochemicals, 300. [See *Chem. Met. Eng.* 34, 586 (1927).]

‡ Colonel Weeks' brief at the hearings was concurred in by Merrimac, Monsanto, and Newport. A West Point graduate, this Calco executive has for years been a prominent figure in the organic chemical industry and in the councils of American Cyanamid. He was born in Lyons, N. Y., and served in the Army through all grades from 2d Lt. to Col., 1905-20. He earned a B.S. in 1910 and an LL.B. in 1912 at the W. Va. U., and joined Calco as asst. secy. in 1920, becoming secy. in 1923.

## REFERENCES

1. *Drug Chem. Mkts.* 17, 979 (1925), 18, 11 (1926); R. J. Quinn, *ibid.* 17, 1595 (1925); E. M. Allen, *Chem. Met. Eng.* 33, 30 (1926).
2. Hearings Agr. & Forestry Comm. (S. 68: 1) on S. 2372, Apr. 18, 1924, p. 110; J. M. Braham, *Trans. Am. Electrochem. Soc.* 48, 211 (1925).
3. *Chem. Mkts.* 20, 781 (1927); *Chem. Met. Eng.* 34, 400 (1927).
4. G. N. Westby, *Ind. Eng. Chem.* 22, 1099 (1930).
5. *Rogers' Industrial Chemistry*, 6th ed., I, 323.
6. *Ibid.* 331.
7. *Chem. Met. Eng.* 34, 75, 124, 135 (1927).
8. *Chem. Mkts.* 21, 49 (1927).
9. *Ibid.* 20, 161 (1927); *Chem. Met. Eng.* 34, 75, 124, 135, 464 (1927); *Fortnightly Rev.* (G. M. P. Murphy & Co., N. Y.) quoted, *Chem. Mkts.* 20, 511 (1927); Co. memo to author.
10. *Chem. Mkts.* 23, 611 (1928), 24, 183 (1929); *Chem. Met. Eng.* 35, 769 (1928); Co. memo to author.
11. Wm. Callan, Hearings Agr. & Forestry Comm. (S. 68: 1) on Muscle Shoals (S. 139, etc.), May 17, 1924, p. 993; Curtis, *Fixed Nitrogen*, p. 151; Dept. Agr., Fixed Nitrogen Res. Lab., *Nitrogen Fixation*, p. 8 (1926). See also *Ind. Eng. Chem., News Ed.* 5 (Jan. 10, 1924); *Drug Chem. Mkts.* 14, 709, 1089 (1924); *Chem. Met. Eng.* 31, 769 (1924).
12. C. O. Brown, to author, Mar. 30, 1946.
13. E. R. Bartlett, to author, Mar. 14, 1946; *Drug Chem. Mkts.* 14, 1943 (1924).
14. *Ibid.* 16, 262 (1925); *Ind. Eng. Chem., News Ed.* 2 (Sept. 10, 1924).
15. *Drug Chem. Mkts.* 16, 1415 (1925).
16. *Ibid.* 1635; *Chem. Mkts.* 25, 625 (1929).
17. *Chem. Met. Eng.* 33, 118 (1926).
18. Co. memo to author.
19. *O.P.D. Repr.* 48 (June 7, 1926); *Ind. Eng. Chem., News Ed.* 5 (June 10, 1926); *Chem. Met. Eng.* 33, 382 (1926); *Chem. Mkts.* 19, 189 (1926).
20. *Chem. Mkts.* 20, 1 (1927); *O.P.D. Repr.* 111 (Jan. 10, 1927).
21. *O.P.D. Repr.* 20 (Feb. 20, 1928).
22. *Ibid.* 21 (June 6, 1927), 44 (Jan. 20, 1930); *Chem. Mkts.* 20, 821 (1927); *Chem. Met. Eng.* 34, 187, 388 (1927); *Min. Ind.* 1927, 539.
23. *Chem. Mkts.* 25, 177 (1929).
24. Quinn, *op. cit.*; Ernst, *Fixation of Atmospheric Nitrogen*, pp. 94, 121.
25. *Chem. Mkts.* 18, 325 (1926); J. C. Woodruff, *Ind. Eng. Chem.* 19, 1147 (1927).
26. Braham, *op. cit.* 219.
27. *Chem. Mkts.* 24, 407 (1929).
28. *Ibid.* 25, 401 (1929).
29. *Ibid.* 20, 358 (1927); *Proc. 2d Intern. Conf. Bituminous Coal* 2, 202 (1928).
30. *Chem. Mkts.* 20, 9 (1927); *Chem. Met. Eng.* 38, 82 (1931).
31. Braham, *op. cit.* 211; F. G. Liljenroth and M. Larsson, U. S. Pat. 1,673,691 (1928), ass. to Phosphorus-Hydrogen Co.
32. *Drug Chem. Mkts.* 18, 627 (1926).
33. Brown, *op. cit.*; *O.P.D. Repr.* 24 (June 18, 1928).
34. *Ind. Eng. Chem., News Ed.* 9, 105 (1931).
35. *Ind. Eng. Chem.* 20, 719 (1928). See also D. H. Killeffer, *ibid.* 19, 1077 (1927); R. S. McBride, *Chem. Met. Eng.* 35, 52 (1928).
36. L. A. Pratt, *Survey of American Chemistry (1925-26)*, I, 69.
37. C. L. Parsons, *Ind. Eng. Chem.* 19, 789 (1927); G. B. Taylor, *ibid.* 1250.
38. *Chem. Met. Eng.* 27, 1278 (1922); *Am. Druggist* 71, 52 (1923).
39. A. E. Marshall, *Survey of American Chemistry (1926-27)*, II, 99.
40. Taylor, T. H. Chilton, and S. L. Handforth, *Ind. Eng. Chem.* 23, 860 (1931).
41. Brown, *op. cit.*; A. P. Beardsley, to author, Apr. 16, 1946.
42. Curtis, *op. cit.* p. 378.
43. Parsons, *Ind. Eng. Chem.* 11, 541 (1919).
44. F. H. Dotterweich, *Refiner Natural Gasoline Mfr.* 21, 51 (1942); Shreve, *Chemical Process Industries*, p. 397.
45. *Chem. Met. Eng.* 30, 948 (1924); 38, 40 (1931).
46. *Ind. Eng. Chem.* 22, 433 (1930); *ibid.*, *News Ed.* 6, 5 (1928); *O.P.D. Repr.* 24 (Feb. 27, 1928); *Chem. Mkts.* 22, 532, 644 (1928).
47. Co. memo to author.
48. *Chem. Mkts.* 23, 646 (1928).
49. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 7, 1929, p. 15.



## Chapter 7

### PHOSPHORUS COMPOUNDS

FLOTATION ADOPTED IN PHOSPHATE MINING—MOROCCO CAPTURES EUROPEAN MARKET FROM U. S.—DOMESTIC ROCK EXPANDS IN PHOSPHATES FOR BAKING POWDER AND INDUSTRIAL CHEMICALS—SWANN CAMPAIGNS FOR CONCENTRATED FERTILIZERS; SELLS ELECTROTHERMAL PROCESS ABROAD, BUILDS FRENCH PLANT—VICTOR MAKES HIGH-TEST PHOSPHORIC ACID IN BLAST FURNACE—LILJENROTH IMPROVEMENT IN WET PROCESS ACQUIRED BY DU PONT—PHOSPHATES ADVANCE IN SUGAR REFINING, RUSTPROOFING, PLASTICIZERS.

**P**HOSPHORIC ACID and its compounds fulfilled, during the twenties, the promises of technical progress and new products implied in the wartime developments. While pyrolytic methods of producing this acid by volatilization of phosphorus from phosphate rock in the electric or blast furnace did not shelve the older wet process—nor indeed have they done so to this day—nevertheless both new processes became successful industrial operations. The various sodium phosphates had an astonishing growth during these years equalled by few industrial chemicals. Output leaped from less than 45,000,000 pounds at the end of the war to more than 290,000,000 in 1929.\* The excellent detergent and water-softening powers of trisodium phosphate had been learned and became the basis of the principal outlet for these salts, eclipsing the original use of the disodium salt in dyeing and weighting silk.<sup>1</sup>

During these years also, the first organic phosphorus compounds made their appearance, the tricresyl, triphenyl, and tributyl phosphates.† They were promptly recognized as valuable plasticizers for the new nitrocellulose lacquers. It was not long before their fire-retarding qualities were also appreciated.

Even at the very base, the mining of phosphate rock, the quickening touch of technological progress was felt. After an exasperating, tedious research that began in 1922 at Mount Pleasant, Tennessee, and reached

\* Production figures for the various sodium phosphates, 1923-29, will be found in Appendix XXI. For good survey of period, see W. H. Waggaman, *Trans. Am. Inst. Chem. Engrs.* 14, 175 (1922).

† Strictly speaking these esters of phosphoric acid are not organophosphorus compounds, in which phosphorus and carbon should be directly linked, but commercially they remain the best known and most important of the phosphorus derivatives containing an organic radical. [See W. C. Davies, *Ind. Chemist* 19, 7 (1943).]

a practical, working-unit stage four years later at Mulberry, Florida, the flotation process of minerals separation was applied to the recovery of phosphate rock. The solution of this problem proved to be more troublesome than it appeared. Besides the physical and mechanical difficulties of handling and preparing the fines, which it was found must be confined to a maximum particle-size range of 28 to 35 mesh, the low-cost commodity handled prescribed pretty severe dollars-and-cents limitations. Later the range size was increased to 14-28 mesh by agglomerative tabling, but from the start it was obvious that considering initial plant investment and capacity, the usual sulfide practice must be ruled out and that construction and working costs must be kept below anything then known in flotation metallurgy. Balancing these obvious obstacles were the tangible rewards to be won by a more complete recovery of pay rock with the alluring prospect in the offing of being able to rework profitably the great waste piles that were growing beside every washer plant in the Florida and Tennessee fields.

Inspired by John Jay Watson,\* the International Agricultural Corporation tackled these problems with determination to find a practical solution. The project dovetailed with Watson's plan to develop to the uttermost the phosphate properties of this big fertilizer company. An outside executive with a successful financial and managerial record, he had been brought in as treasurer in 1913. Thoughtful comparison of the position of a large fertilizer manufacturer with that of the smaller dry-mixers convinced Watson that control over the chief raw material of the most important plant-food ingredient, superphosphate, was the sole, exclusive asset of the big company.† The small operators enjoyed, as an offset, modest plant investment and a neighborhood market, which meant lower selling and freight costs. To fortify his company's strong point, Watson faithfully supported this research until 1928, when a complete, commercial-scale flotation unit was finally put into operation adjacent to the mines at Mulberry.

James A. Barr ‡ was assigned to this task. He set up a laboratory

\* Watson was born in Jamestown, R. I., Nov. 12, 1874, and started in business with the Industrial Trust Co., Providence. A stocky, square-jawed, decisive executive, he early displayed exceptional ability. At 23 he was elected Moderator of the Town of Jamestown; at 25, treas. of the Jos. Banigan Rubber Co.; at 27, a member of the R. I. House of Representatives. In 1908 he came to N. Y. City as treas. of the United States Rubber Co. From 1910-13 he was partner of the Wall St. house of Watson & Pressprich, when he became treas. of International Agricultural and pres. in 1923. He was dir. of numerous firms; served the Nat. Fertil. Assoc. as pres. for 2 terms; he was decorated by the French Govt. with the Legion of Honor. He died, Mar. 30, 1939.

† The fertilizer industry, as such, is discussed in Chap. 19.

‡ A min. engr., trained at the Mich. Coll. Mines (B.S., M.E., 1907), Barr became asst. engr., Tenn. Div., International Agricultural Corp., 1912, and engr., 1914. From 1916-21 he was in private consulting practice, returning to International as chief engr. in particular charge of these flotation investigations. He served the town of Mt. Pleasant, Tenn., as

flotation machine in the Mount Pleasant plant. Cut-and-try experiments were discouraging until he began following the trail blazed by Broadbridge and Edser,\* calling into consultation the engineers of the Minerals Separation North American Corporation. In 1926 the experiment was transferred on a semi-plant scale to Florida.† As finally perfected this process depended upon careful desliming, maintenance of the optimum pH by the use of caustic soda, and the employment of oleic acid and fuel oil as a flotation agent.<sup>2</sup> Shortly before Barr's plant opened, the Tuscaloosa, Alabama, Station of the Bureau of Mines carried on a series of flotation tests and reported that as much as 84 per cent of the phosphate in undersized material rejected by the chamber screen at the Florida pebble-washing plants, could be recovered by means of the oleic acid-sodium oleate flotation method.<sup>3</sup>

These were certainly worthwhile results, and although the continued unsatisfactory state of the fertilizer market delayed the general adoption of flotation recovery, nevertheless, from this time on the process became an increasingly important adjunct to rock mining. The use of flotation methods have virtually doubled the phosphate reserves of Florida. In Tennessee, where the nature of the rock and matrix do not fit this process so well, Allen cones and other mechanical ore-dressing devices, introduced by Hoover & Mason, Armour, and International, have been extensively and successfully adopted.<sup>4</sup>

In rock mining, where the larger fertilizer manufacturers had become the chief producers, there were few changes during the twenties. Outstanding events were the final abandonment of work on the South Carolina deposits in 1925,<sup>5</sup> and the appearance of the Davison Chemical Company as a rock producer. In 1928 Davison and Hayden, Stone & Company bought approximately 220,000 shares of the Southern Phosphate Corporation at \$9.38 a share, or somewhat more than \$2,000,000 to be paid in ten years, with interest at 6 per cent. Davison was to operate the property which consisted of modern plants at Bartow and Lakeland, Florida, and had reserves estimated to exceed 23,000,000 tons. This purchase did not upset the market. Southern Phosphate had long

member of the school bd. and alderman. He is the author of *Testing for Metallurgical Processes* (1910).

\* U. S. Pat. 1,547,732 (1925).

† "We did not make any consistent progress in 1927 until we recognized the difference in action between a fatty acid and a glyceride. Some natural oils gave fair results one time and poor with other samples, the difference being due to the amount of free fatty acid liberated by aging or hydrolysis. The results followed the percentage of fatty acid present. I might add that I visited Anaconda late in 1926 and Ernest Klepetko told me they had tried phosphate flotation on Western ores and had given it up. He kindly had a beautiful bronze laboratory flotation machine made for me in their shops, which I used in March 1927 for the first successful tests at Mt. Pleasant and which started the ball a-rolling." (James A. Barr, to author, Apr. 11, 1946.)

supplied Davison with its phosphate rock and Davison's president, C. Wilbur Miller, had been a director of the phosphate company for some ten years. Chester A. Fulton,\* who had been managing the Davison Sulphur & Phosphate operations in Cuba, took over active administration of the Southern Phosphate Corporation.<sup>6</sup>

Abroad, American phosphate rock met more determined and much more successful competition from the North African mines. World War I dealt some trump cards to the strong hands already held by the African producers. They had always had advantages in cost. They employed considerable convict labor which was not only cheaper but more efficient and physically fit than native workmen. The location of the mines in the highlands skirting the seacoast enabled them to ship their rock downgrade by gravity. Ocean freight rates to the principal European ports were about half those from Florida. Prior to 1914, however, the higher grade of Florida hard rock, averaging from 70 to 80 per cent B.P.L.† against 58 to 68 per cent for Tunisian and Algerian material,<sup>7</sup> gave American exporters first call in the European markets, then consuming roughly half of our production. Due to shipping stringencies, our exports, which had averaged over a million tons prewar, dwindled to 143,456 tons.‡ Compelled to take in North African rock, European makers of superphosphates learned what American fertilizer manufacturers had already discovered, namely that the lower-grade material was perfectly satisfactory for acidulation, and that the softer physical composition of North African rock (as compared with Florida land pebble) was a slight but distinct advantage. While chemical employment of phosphatic material was greater in Europe than in the United States, nevertheless there, too, the greatest consumption was in the production of superphosphate for fertilizer. The war experience thus underscored the cost advantages of the lower-grade, North African phosphates in this important market.

The American advantage of concentrated material was threatened in 1921 by the appearance of high-grade rock, averaging from 70 to 78

\* From the Columbia School of Mines (M.E., 1906), Fulton went as mill boss and mine supt. in Mexico and Central America before going to Cuba in 1916 to investigate copper-pyrites properties for Davison and to become mgr. of Davison Sulphur & Phosphate in 1919. Serving with him on the original bd. dir. of Southern Phosphate were Warner D. Huntington and E. B. Miller of Davison; Benj. F. Newcomer, the Baltimore banker; W. F. Carey, the sanitation commissioner; and Charles Hayden and Richard F. Hoyt of Hayden, Stone & Co. He became vice-pres. in 1929; pres. in 1932; and in 1933, when Davison went into receivership and the stock returned to the original owners, he remained at head till Jan. 31, 1945, when he retired. Fulton was pres., Am. Inst. Min. Met. Engrs., 1944.

† Phosphate rock is sold on the basis of its content of phosphorus calculated as tricalcium phosphate, commercially known as bone phosphate of lime, hence B.P.L. Exports of Florida hard rock are commonly of 77% B.P.L. (See Vol. II, p. 184.)

‡ For statistical details of the war years, see Vol. II, p. 373.

per cent B.P.L., from Morocco.<sup>8</sup> These rich, conveniently located deposits in the hinterland of Casablanca had been discovered in 1912. They were not worked until 1921, when they were taken over by the Moroccan Government for vigorous exploitation.<sup>9</sup> L'Office Chérifien des Phosphates, in charge of developing the Morocco mines, recognized nicely its strategic position. It scrupulously protected the interests of private French capital invested in the Algerian and Tunisian properties, but it made no secret of its intention to challenge American high-grade rock in world markets. It developed the mines vigorously and skillfully with the best engineering advice. It pursued a pugnacious sales policy. The growth of its business was phenomenally rapid and by 1929 production from Morocco stood second to the United States and Tunis. Since in these North African countries production was virtually synonymous with exports, they were already definitely in control of the international market.\* They completely eliminated American rock from Great Britain and supplied most of the imports to European countries except Germany, Scandinavia, Holland, and Belgium.<sup>10</sup>

Capture of the European market did not content the North African producers. In 1925 they began exporting to South Africa, in 1926 to Australia, in 1927 to the United States itself. The last was adding insult to injury, and early in 1928 Secretary of the Treasury Mellon issued an antidumping order prohibiting the importation of Moroccan rock.<sup>11</sup> But the charge of selling below cost could not be substantiated. Thereupon the fertilizer industry took the case to Congress. Efforts were made to throw up two distinct lines of defense. First, Congress was urged to broaden the law prohibiting the importation of goods manufactured by convict labor to include commodities grown or mined; second, amendment of the Tariff Law was proposed, introducing protective duties on phosphate rock.<sup>12</sup> Both efforts failed. Congress was reminded that phosphate rock is a fertilizer ingredient and that the farm bloc is unalterably opposed to any duties on any plant-food materials.

The sharp curtailment of exports to Europe was not the only challenge to American phosphate rock supremacy. The most concentrated form of phosphates known occur on certain South Pacific and Indian Ocean islands, and the Dutch island of Curaçao in the West Indies. These surface deposits are the result of bird guano, leached by rain, its soluble phosphate content fixed by the underlying coral formations.

\* "The Russians had developed a large deposit of apatite-type phosphate rock. I am under the impression that it was concentrated by flotation. It was quite high-grade, but rather difficult to acidulate largely because of lack of carbonates. During the period, the Soviet Govt. shipped one or more cargoes of this apatite material to the U. S. Customs clearance was refused on the claim that the rock was produced by slave labor. As I recall the shipments were finally admitted." (C. H. MacDowell, to author, Apr. 21, 1946.)

They yield a material that runs from 80 to 88 per cent calcium phosphate.<sup>13</sup> These deposits first attracted commercial attention about the beginning of the century, exploitation of Ocean Island beginning in 1900, of Nauru in 1906, and Makatea in 1912. Naturally these sources were drawn upon heavily during the war and afterwards British, French, and Japanese interests continued to exploit them energetically,<sup>14</sup> so that they continued to supply most of the Australian requirements and a good part of the Japanese.

The inroads of these foreign competitors cut down our exports of phosphate rock sharply during the twenties. Fortunately for the American producers domestic consumption grew to some 2,000,000 tons annually. This, with the 750,000 tons exported, actually increased the total consumption over prewar totals.\* The greatest domestic chemical growth was in the various sodium phosphates. These salts had long been produced by three groups of companies whose major activities centered upon fertilizers, industrial chemicals, and baking powder.

Among the fertilizer companies were the Bowker Chemical Company and the Phosphate Products Corporation, subsidiaries of the American Agricultural Chemical and the Virginia-Carolina Chemical Companies, respectively. During the twenties these were joined by the International Agricultural Corporation, which built a \$250,000 plant at Wales, Tennessee,<sup>15</sup> where it produced not only di- and trisodium phosphate, but triple superphosphate and ammonium phosphate of fertilizer grade. The Anaconda Copper Company also began to make the triple superphosphate at its Anaconda, Montana, plant, adding a small unit for monoammonium phosphate.<sup>16</sup>

Of the heavy chemical manufacturers, General, Grasselli, and Warner † had all produced phosphate salts prior to the war. All three expanded their production during the twenties, the General Chemical Company notably increasing the capacity of its Delaware works ‡ in

\* Statistics of production, exports, and imports, 1923-29, and consumption in direct application to the soil and in the manufacture of chemicals and superphosphate are in Appendix XXII.

† Now Westvaco Chlorine Products Corp.

‡ "I was with General Chemical from 1907 to 1922 and spent many months at the Delaware works—it is not in Delaware but on the Delaware River at Marcus Hook, Pa.—in the phosphate plant, which was the most beautiful example of the old coordination theory that I have ever seen. Rio Tinto cuprous pyrites was landed in shiploads at the plant, which was right on the river, perhaps the finest harbor in the world. The ore was burned to make sulfuric acid and the cinder was passed to the Nichols Copper Co. for desulfurization, smelting, and copper recovery. The sulfuric acid was mixed with Chile saltpeter, also received by water at the plant, and retorted to produce nitric acid and niter cake (about 65%  $\text{Na}_2\text{SO}_4$  and 35%  $\text{H}_2\text{SO}_4$ ). Some of the niter cake was mixed with salt and roasted in Herreshoff roasters to yield muriatic acid and salt cake. The latter was reduced with coal to crude sodium sulfide, from which purified sodium sulfide and sodium thiosulfate were made. The balance of the niter cake was digested

1925 and in 1926, and again in 1928. In 1927 a newcomer appeared in this field, the Blockson Chemical Company of Joliet, Illinois, organized by J. William Block, founder also of the Superior Chemical Company, while the following year the American Cyanamid Company also began to make phosphate salts.<sup>17</sup>

Joint testimony to the growing use of trisodium phosphate and the decentralization of the industry came in 1929 with the first production of this chemical west of the Mississippi. At Los Angeles the A. R. Maas Chemical Company turned out four tons a day, manufactured from natural soda from California trona, treated with phosphoric acid prepared by Anaconda Copper from its Idaho phosphate beds.

A. R. Maas, who was professor of pharmacology and toxicology at the University of Southern California, was appealed to in 1918 by some of the local moving picture companies to save them from threatened stoppage of their business for lack of sodium hyposulfite and sulfite, necessary for developing their films. Thus accidentally, and perhaps almost unwillingly, Maas entered chemical manufacturing in a second-hand bath tub. The movie studios were pulled through their crisis. Maas liked manufacturing and gradually shifted away from teaching and dropped it entirely. In 1929 Fred C. Bowman,\* who had spent years in phosphate manufacture in the East, joined the staff of the A. R. Maas Chemical Company and manufacture of trisodium and disodium phosphates was begun.<sup>18</sup>

Amid a violent storm of claims and counterclaims, the phosphate baking powders continued to grow in popularity until, during the twenties, it was generally acknowledged that next to fertilizer superphosphate, they were the largest consumer of both bone and phosphate rock. Modern baking powders consist of a dry mixture of sodium bicarbonate with an acidulating chemical capable of completely decomposing it, such as the salts of phosphoric acid—sodium and potassium acid phosphates—tartaric acid, the acid tartrates, or alum. Government regulations require the evolution of at least 12 per cent  $\text{CO}_2$  and permit only the slightest traces of arsenic, lead, zinc, copper, or the fluorides.

with Florida phosphate rock to yield dilute phosphoric acid and sodium sulfate, which solution was fed to furnaces of the black-ash revolver type to produce crude trisodium phosphate, which was purified. It was magnificent integration, but awfully inflexible and almost every step is now fighting for its life against more flexible but less integrated processes." [F. C. Bowman, to author, June 3, 1946; see also A. R. Maas, *Chem. Met. Eng.* 52, 112 (1945).]

\* Bowman, whose father and grandfather had also been in the heavy chemical business was born in Canada, July 3, 1883, and grew up in a sulfuric acid plant which he entered formally as a bottle washer at \$2 a week. He graduated from U. Toronto in 1906, won the gold medal of Victoria U., and took a job as chem. with the General Chemical Co. Bad health sent him to Calif. in 1921 and after he recovered, he joined the A. R. Maas Chemical Co. of which he is still dir. research.

Competition in the trade is intense and contentious. In 1920, for example, the Royal Baking Powder Company, making a tartrate product, was haled before the Federal Trade Commission charged with unfair competition because it advertised that alum baking powders are objectionable. Trial Examiner E. M. Averill reported, November 12, 1925, and the complaint and several supplementary ones were all dismissed, March 23, 1926.<sup>19</sup>

Because of the secretiveness of the industry, no detailed figures are available of the quantities of the various types sold. The estimate made late in the twenties of a total production of over 25,000,000 pounds annually<sup>20</sup> is probably conservative, though it gives no guess as to the comparative standing of the various acidulating agents. For this purpose, four phosphate compounds are used: monocalcium phosphate ( $\text{CaH}_4(\text{PO}_4)_2$ ), monopotassium phosphate ( $\text{KH}_2\text{PO}_4$ ), monosodium phosphate ( $\text{NaH}_2\text{PO}_4$ ), and sodium acid pyrophosphate ( $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$ ).<sup>21</sup>

Because of stringent government regulation, further encouraged by popular prejudice in favor of bone as against rock as the source material and by its peculiar market in the bakery industry and grocery trade, the manufacture of baking-powder phosphates has grown up as a quite distinct branch of the chemical industry. An early exception was the Warner Chemical Company, using rock as a raw material and producing besides the industrial sodium phosphates, the leavening agent, sodium pyrophosphate. This development that stems from the invention of William D. Patten was implemented by Warner's ownership of the subsidiary, Monarch Chemical Company, manufacturers of baking powder.<sup>22</sup>

Like Warner, two of the largest producers of this period, the Rumford Chemical Works at Rumford, Rhode Island, and Wilckes-Martin-Wilckes Company at Camden, New Jersey, were producing for their own manufacture of baking powders. During the twenties they were joined by the Calumet Chemical Company of Joliet, Illinois, which in 1927 installed A. M. Lawson, formerly with the Victor Chemical Works, as its chief chemist and director of development.<sup>23</sup> The Victor Chemical Works in Chicago and Provident Chemical Works in St. Louis continued to produce the widest variety of phosphates,\* assiduously cultivating baking-powder trade and the manufacturers of self-raising flour. In 1923 Theodore Swann gathered into his Federal Phosphorus Company the Provident Chemical Works and while its president, Sydney H. Thomson,† retired, two other executives, the

\* For a list of firms producing all types of phosphates from rock in 1928, see Appendix XXIII.

† Thomson, an Englishman born in Liverpool, Oct. 6, 1861, came to this country as a young man and was for many years with the Guide Printing & Publishing Co.,



chief chemist, Paul Logue,\* and the sales manager, Douglas Boyer,† joined the Swann organization. Supplying the Provident operations with acid from his electric furnaces at Anniston, Alabama, Swann expanded production until his company became one of the largest makers of monocalcium phosphate in the country. In 1929 he stepped still further into this field by acquiring a controlling interest in the Iliff-Bruff Chemical Company of Hoopeston, Illinois.<sup>24</sup>

Outside of this tripartite grouping of phosphate producers was the Phosphorus Compounds Company, which had been launched in 1903 at Niagara Falls as a joint venture of the Mallinckrodt Chemical Works and the Oldbury Electro-Chemical Company. It prepared 85 per cent or 90 per cent phosphoric acid from elemental phosphorus and a unique line of hypophosphites, phosphorus chlorides, and zinc chloride. Oldbury bought out the Mallinckrodt interests and took over the plant and products in 1927.<sup>25</sup>

Behind and overshadowing all these commercial activities were technical developments in the pyrolytic production of phosphoric acid from phosphate rock. Though the pioneering American work in electrical methods was done in the Bureau of Soils under Dr. Whitney, by Ross, Carothers, and Merz, credit belongs to Theodore Swann for applying the process commercially.<sup>26</sup> Plant-scale operation naturally demanded much research that led to many modifications, and in 1924 Swann himself testified at the Muscle Shoals hearings,<sup>27</sup> that to date his company had smelted 94,000 tons of phosphate rock after an expenditure of over \$5,000,000 for experimental and operating expenses. At the same time he reported that in spite of rapid improvements in electric-furnace techniques, they were experimenting with fuel-fired furnaces in the hope of perfecting cheaper methods. While the Federal Phosphorus Company was thus wrestling with practical operating problems, a small output of elementary phosphorus came from the Piedmont Electro Chemical Company which started electric-furnace smelting of phosphate rock and phosphoric acid production at Mount Holly, North Louisville. He became treas. of the newly formed Provident Chemical Works in 1896 and pres. in 1918.

\* Logue, who did extensive research in leavening agents, detergents, and high-test fertilizers, began his career in the coal-tar dyes field where he was successively with Federal Dyestuff, Atlantic Dyestuff, and National Aniline, before becoming chief chem., Provident Chemical Works. In 1931 he moved to Birmingham as chief chem. of the Swann Corp. and after its interests were acquired by Monsanto in 1936, he became vice-pres. in charge of mfg. of the new Swann & Co., and in 1938, dir. development of the Phosphate Div. of Monsanto. He was born in Hampshire, Tenn., Aug. 12, 1895, and educated at the U. Tenn., A.B., 1916.

† Boyer went with Monsanto after the consolidation, becoming asst. sales mgr. He was born at St. Joseph, Mo., Aug. 27, 1896; he studied at the Harvard Business Sch.; and for 8 yrs. before joining Provident in 1925, had been secy. of the Mo. Grain Dealers & Millers Assoc. He died tragically in a Chicago hotel fire, June 1946.

Carolina, in 1914-15, under the direction of the brilliant Austrian chemical engineer, Hechenbleikner. The furnace was rated at 5,000 kilowatts and the phosphoric acid produced was consumed in ammonium phosphate production for fertilizer consumption. Some triple superphosphate was also made. Subsequently, this operation was changed to produce monocalcium phosphate for leavening purposes. The Mount Holly operation followed more than a year of experimental work at Charlotte, North Carolina, which was participated in by Willson and Haff of calcium carbide fame. The output of phosphorus at Mount Holly was on a relatively small scale and proved uneconomic because of power costs.<sup>28</sup>

Strong phosphoric acid having been made available by the Federal Phosphorus Company commercially—the Phosphorus Compounds Company output was consumed by Mallinckrodt—new chemical opportunities were thrown open which the industry in this country did not immediately grasp. This difficult and expensive accomplishment was due to the combined contributions of two very different individuals: the mild, studious, soft-spoken John N. Carothers and the driving, exuberant, enthusiastic Theodore Swann. Carothers laid a sound technical foundation under the pyrolytic process. Swann, in spite of his brilliant vision and real sales ability, was unable to build a substantial profitable chemical business. The end of the war had caught him in a bad position. He had a large investment in electric furnaces for the production of ferromanganese when the sudden collapse of the German Army foreclosed any opportunity to amortize these fixed charges. The intelligent, almost visionary switch of this operation to production of phosphoric acid undoubtedly took longer and cost more than Swann had anticipated. He was loyally backed by his old employer, the Alabama Power Company, which was logically interested in encouraging any promising electric-furnace development within its territory. The phosphorus operation at Anniston was a very profitable enterprise and paid all the losses from the interrupted ferromanganese venture, the costs of working out a successful phosphorus process and of its operating equipment, as well as for several ill-advised excursions outside the making of pure, high-test phosphoric acid and with it food and chemical phosphates. Nevertheless, Swann was compelled to accumulate an indebtedness for power that at one time reached \$800,000.<sup>29</sup>

Obviously the most promising outlet for large quantities of this acid was in the fertilizer field for acidulation of rock to produce the so-called triple superphosphate,\* or in the manufacture of the concentrated ni-

\* Often, and less exactly, called "double superphosphate," produced by the following reaction,  $\text{Ca}_3(\text{PO}_4)_2 + 4\text{H}_2\text{PO}_4 = 3\text{CaH}_4(\text{PO}_4)_2$ . It contains from 40-60%  $\text{P}_2\text{O}_5$  as against

trogen-phosphorus plant foods, mono- and diammonium phosphates.\* Swann foresaw all this. At Congressional hearings, May 12, 1922,† he proposed that Muscle Shoals' power be used in the electric-furnace process to produce phosphoric acid for the manufacture of triple superphosphate, a plan which years later was adopted by the Tennessee Valley Authority.‡ He did more than propose. Thanks largely to the work of Bethune G. Klugh, a highly concentrated chemical plant food in pellet form was produced—the first American rival of similar products being introduced at this time by the Germans—and the Jax Plant-food Company was organized. This premature venture never had even a chance of success. The cost of the acid was too high; expensive plant was needed to manufacture it; new and special equipment was required to apply it to the soil. Finally an enormous promotional and educational campaign was necessary to sell it, because, if the fertilizer industry was then unprepared to adopt plant-food concentrates, the farmer viewed them with undisguised distrust.<sup>30</sup>

Interest in high-test fertilizers was more lively abroad, and rather ironically the first commercial adaptation of this American process § was made in France, and backed by the most determined foreign rival of the American phosphate rock industry. In 1927 Swann disposed of the French and Italian rights to his electrothermal process to the Société des Phosphates Tunisiens.<sup>31</sup> This agreement called for collaboration in building a plant at Pierrefitte, nestled in the upper Pyrenees, and the French engineers, Seladeux and de Jonigan, came to Anniston while Robert R. Cole §§ went to France during 1927-29 in charge of construc-

a soluble phosphate content of 16-20% in the ordinary superphosphate prepared by acidulating with  $\text{H}_2\text{SO}_4$  and containing quantities of gypsum.

\* American production of fertilizer ammonium phosphates, 84% of which went to Japan and the East and West Indies, was expected to reach 250,000 short tons in 1929 (*Min. Ind.* 1928, 483). It is doubtful this output was ever realized since the 1931 Census reported only 35,488 tons consumed in fertilizers. For the preparation and properties of ammonium phosphates, see W. H. Ross, A. R. Merz, and K. D. Jacob, *Ind. Eng. Chem.* 21, 286 (1929).

† See Vol. II, p. 119.

‡ "While ultimately the largest consumption of phosphoric acid may be in fertilizer, to date, except where some sort of subsidy has existed, I believe the outlets for electric-furnace or blast-furnace phosphoric acid have been mainly in chemical, food, and industrial uses. In so far as I know, only negligible quantities of thermal process phosphoric acid have been used in fertilizer. There are numerous reasons why this situation exists. In the case of TVA, with its favorable financial arrangements, fertilizer production is another story." (J. N. Carothers, to author, Apr. 8, 1946.)

§ For pro and con of "American" origin of this process, see *Ind. Eng. Chem., News Ed.* 11 (Mar. 10, 1928).

§§ Cole had been chief engr. and later gen. supt. of Swann's Southern Manganese Corp. and when Monsanto took over in 1935 he became asst. to R. J. Hawn, vice-pres. In 1938 he became prod. mgr. of the Phosphate Div.; in 1939, gen. mgr. of the Div. Res. & Sales; in 1941, vice-pres. of Monsanto. He is keenly civic-minded and was dir., Assoc.

tion. He was followed by W. R. Seyfried and Earle Dunlap who put the plant in initial operation. The plant of the Tunisian company produced diammonium phosphate, and early in 1929 achieved the first large-scale output of this concentrated fertilizer ingredient in the world.<sup>32</sup>

In the late twenties, when the Federal Phosphorus Company decided to investigate blast-furnace methods, it was returning to an older rock-to-acid route. The Victor Chemical Works had blazed this trail. Advised by Charles Frederick Chandler, Columbia University professor of chemistry, who, at the turn of the century, inspired and instructed many pioneering chemical enterprises, August Kochs, Victor's founder, had adopted rock instead of bone as a raw material for the manufacture of baking powder phosphates. Chemically and economically this was sound. But this change necessitated several years' research, particularly to eliminate impurities, notably fluorine. Parallel work to concentrate and improve the quality of rock by means of calcination \* and Victor's own current experiments with the electric furnace naturally suggested the blast furnace for commercial production of a high-grade phosphoric acid.

Prior to 1920 Victor installed at Chicago Heights an experimental electric furnace, and in 1925 initiated work on a small-scale blast furnace. In 1927 it was decided to adopt the fuel-fired process and to rebuild the burnt wet-process plant at Nashville, Tennessee, upon the new basis.<sup>33</sup> This installation, which had an initial daily capacity of 75,000 pounds of  $P_2O_5$ , using Cottrell precipitators to collect the acid, came on line early in 1929 and continued in operation until a larger unit was built several years later.<sup>34</sup> Until 1928 the total investment of the Victor Chemical Works in plant and research was \$4,000,000.<sup>35</sup>

In the meantime the wet process of producing phosphoric acid by treating rock with sulfuric acid had also been progressing. By 1927 the continuous countercurrent decantation system, known as the Dorr process, had been installed by all but a few smaller manufacturers of phosphoric acid and triple superphosphate.<sup>36</sup> This marked economic and technological improvement was further supplemented by a process perfected by Frans G. Liljenroth, the rights to which for North America,

Industries of Ala.; pres., Anniston Chamber of Commerce; and pres., Southern States Industrial Council.

\* Enrichment of Florida pebble so as to compete with hard rock prompted the Coronet Phosphate Co. to calcination investigations at its Plant City, Fla., operation. A working process—covered by U. S. Pat. 1,192,545, issued to C. G. Memminger, July 25, 1916—resulted and it was applied in 2 calcining units with a daily capacity of 600 tons. Material of a grade suitable for export and to meet the especial requirements of baking powder and fine chemicals was produced more or less continuously for 12 yrs., but no technical details were made public till 1930. [See Memminger, W. H. Waggaman, and W. T. Whitney, *Ind. Eng. Chem.* 22, 443 (1930).]

China, and Japan were acquired in 1927 from the Electric Bond & Share interests by E. I. du Pont de Nemours & Company.<sup>37</sup>

These developments had considerably broadened the base of phosphoric acid, making it a more available chemical tool. This was reflected not only in the development of new uses in organic synthesis, but also in greater employment in sugar refining and as a rustproofing agent.\*

Thanks to the development of the Parkerizing process, which supplanted earlier costly and uncertain methods,<sup>38</sup> this last important application grew rapidly during the 1920's. This method of rustproofing is accomplished by immersing the iron or steel article in a metallic acid phosphate solution which reacts chemically with the iron or steel until the entire surface is converted to an insoluble phosphate coating that is highly resistant to corrosion. The practical use of this method was earlier improved by F. R. G. Richards and W. H. Allen,† and after the organization of the Parker Rust-Proof Company, by a series of refinements developed by Matthew Green, Dr. H. H. Willard, and Elmer M. Jones. In 1926 the first rapid phosphate coating process was put into commercial operation by the Parker Rust-Proof Company under the name of Bonderite. The introduction of accelerating agents into the phosphate solution saved sufficient time to permit the treatment of articles on conveyor-line production, and this accelerated treatment produced thin, adherent coatings suitable for subsequent painting.

The growing importance of all kinds of phosphorus compounds had some commercial repercussions. Despite the expansion of American production, imports both of acid and salts continued.‡ The American sales agency for industrial sodium phosphates manufactured by the Gebrüder Giuliani G.m.b.H., acquired from the Meteor Products Company by the Rhodia Chemical Company, was transferred in 1938 to Harshaw, Fuller & Goodwin of Cleveland, shortly before the Rhodia business was sold to the Newport Chemical Company.<sup>39</sup> Competition between importers and American manufacturers was keen, and in the autumn of 1926 the Treasury Department heard formal charges that 10 tons of phosphoric acid had been dumped in New York at the price of \$10 a hundredweight, f.o.b. Rotterdam. Investigation developed that this price figured out at \$8.70 a hundredweight at the German factory, and although the current quotation in New York was \$16, it was ruled that no unwarranted price below German quotations had been made.<sup>40</sup>

At the Tariff Readjustment hearings in 1929, F. Austin Lidbury, presi-

\* Phosphoric acid was first suggested as a rustproofing agent in 1907 by Coslett.

† Richards, U. S. Pat. 1,069,903 (1913); Allen, U. S. Pat. 1,248,053 (1917).

‡ For detailed statistics of U. S. production of acid and salts, see Appendix XXI; for imports, Appendix V.

dent of the Oldbury Electro-Chemical Company, pointed out a clever evasion of the tariff on phosphorus.<sup>41</sup> Phosphor copper, thanks to its classification as "metals unwrought," had been brought into this country duty-free. No separate import records had been kept, but Lidbury estimated on the basis of a special survey made by his company, that no fewer than 1,800,000 pounds of this alloy were being sold here each year at a value of over \$300,000. Since the sole use of phosphor copper is as a vehicle for introducing phosphorus into bronze, its importation was a clear evasion of the duty on phosphorus, an evasion which was stopped by a later decision of the Treasury Department classifying this material as a "chemical compound." At these hearings the Oldbury Electro-Chemical Company submitted a brief supporting the request for a duty of 6 cents a pound on phosphorus oxychloride and trichloride. These chemicals had assumed a new importance due to their use in several branches of organic chemical manufacturing, notably in triphenyl and tricresyl phosphates, which were coming into general use as plasticizers. There were two makers in the United States, and in 1927 the larger, the Warner Chemical Company, discontinued these items because of German competition, while the Phosphorus Compounds Company was taken over by Oldbury, which extended its facilities to a capacity of 700,000 pounds a year and stated in the brief that with adequate protection, these could be further enlarged to care for domestic requirements.

## REFERENCES

1. J. A. Chew, *Chem. Mkts.* 24, 250 (1929).
2. J. A. Barr, *Ind. Eng. Chem.* 26, 811 (1934); H. S. Martin, *Am. Inst. Min. Met. Engrs. Contrib. No.* 51 (1933); F. L. Bosquil, *Min. & Met.* 21, 501 (1940).
3. *Min. Ind.* 1927, 449; orig., H. M. Lawrence and F. D. DeVancy, *Bur. Mines, Rept. Investigations No.* 2860 (1928).
4. C. H. MacDowell, to author, June 7, 1946.
5. *Min. Ind.* 1925, 549.
6. C. A. Fulton, to author, Apr. 11, 1946; *Poor's Manual of Industrials*, 1930, p. 46; *Chem. Mkts.* 22, 535 (1928).
7. J. Kalish, *Chem. Mkts.* 29, 461 (1931).
8. Waggaman and Easterwood, *Phosphoric Acid, Phosphates and Phosphatic Fertilizers*, p. 95.
9. P. Jumeau, *Am. Fertil.* 142 (Oct. 9, 1920), *ibid.* 106 (June 4, 1921); *Eng. Min. J.* 113, 556 (1922); H. E. Russell, *Bur. For. Dom. Com., Spec. Circ. No.* 105, July 13, 1925; *Min. Res.* 1925, II, 101.
10. Kalish, *op. cit.*
11. O.P.D. *Reptr.* 70 (Feb. 27, 1928).
12. *Min. Ind.* 1929, 489.
13. Waggaman and Easterwood, *op. cit.* p. 97.
14. Barr, to author, Apr. 11, 1946; *Am. Fertil.* 23 (Dec. 13, 1913), 89 (Feb. 11, 1922), 33 (Apr. 22, 1922), 68 (Nov. 3, 1923); *Can. Chem. Met.* 7, 105 (1923); *Min. Res.* 1925, II, 107.
15. *Chem. Met. Eng.* 34, 136 (1927).
16. E. L. Larison, *Ind. Eng. Chem.* 21, 1175 (1929).
17. Co. memos to author.
18. *Chem. Met. Eng.* 36, 476 (1929); F. C. Bowman, to author, June 3, 1946.
19. Darrah, *Modern Baking Powder*; L. H. Bailey, *Dept. Agr., Circ. No.* 138 (1930).
20. Waggaman and Easterwood, *op. cit.* p. 258n.

21. *Ibid.* p. 258, see also Shreve, *Chemical Process Industries*, p. 350; Riegel, *Industrial Chemistry*, p. 132; Bailey, *op. cit.*
22. Chew, *op. cit.*
23. *Chem. Mkts.* 20, 829 (1927).
24. K. D. Jacob, *Trans. Am. Electrochem. Soc.* 48, 282 (1925); C. H. Penning, *J. Chem. Educ.* 7, 2370 (1930).
25. E. L. Whitford, to author, Apr. 11, 1946; *Chem. Mkts.* 21, 559 (1927); *Chem. Met. Eng.* 34, 710 (1927); R. B. MacMullin, F. L. Koethen, and C. N. Richardson, *Trans. Am. Inst. Chem. Engrs.* 36, 315 (1940).
26. T. Swann, *Ind. Eng. Chem.* 14, 630 (1922), *Min. & Met.* 6, 4 (1925); A. H. Hooker, Hearings Agr. & Forestry Comm. (S. 68:1) on S. 2372, Apr. 22, 1924, p. 208; Jacob, *op. cit.* 283.
27. Hearings, *op. cit.* May 19, 1924, p. 1025; D. H. Killeffer, *Ind. Eng. Chem.* 16, 995 (1924).
28. Carothers, to author, Apr. 8, 1946; *Drug Chem. Mkts.* 12, 1043 (1923).
29. Carothers, *op. cit.*; *ibid.*, *Chem. Ind.* 42, 523 (1938); personal interviews with T. Swann, Birmingham, Ala., 1945, and R. R. Cole, St. Louis, 1943.
30. Carothers, *op. cit.*
31. *O.P.D. Reprtr.* 20 (Dec. 12, 1927); *Chem. Mkts.* 22, 68 (1928), 24, 181 (1929); *Chem. Met. Eng.* 35, 42 (1928); B. G. Klugh, *ibid.* 36, 669 (1929); see also Carothers (Federal Phosphorus Co.), U. S. Pat. 1,410,550 (1922).
32. Interview, Cole, *op. cit.*; *Chem. Met. Eng.* 35, 659 (1928).
33. *Drug Chem. Mkts.* 18, 1077 (1926); *Chem. Ind.* 36, S63 (May 1935).
34. Co. memo to author; *Chem. Mkts.* 27, 38 (1930); Carothers, *Chem. Ind.* 42, 525 (1938).
35. Co. memo to author.
36. Waggaman and Easterwood, *op. cit.* p. 195.
37. W. C. Weber, *Chem. Mkts.* 26, 375 (1930), *ibid.* 20, 821 (1927); *Chem. Met. Eng.* 34, 339, 388 (1927); *Min. Ind.* 1927, 456.
38. E. S. Whittier, *Metal Ind.* 16, 509 (1918); L. C. Morrow, *Chem. Met. Eng.* 18, 264 (1918); L. E. Eckelmann, *Raw Material* 5, 438 (1922); see also Waggaman and Easterwood, *op. cit.* p. 279.
39. *Chem. Mkts.* 23, 609 (1928); 25, 65 (1929).
40. *Ibid.* 19, 913 (1926); for current price, see *ibid.* 954.
41. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. I, Jan. 7, 1929, p. 145.

## Chapter 8

### ELECTROLYTIC COMPETITION IN ALKALIES

ALKALI OUTPUT EXCEEDS WARTIME RECORDS—AMMONIA-SODA COMPANIES ADOPT ELECTROLYTIC PROCESS—ALKALI PRODUCERS UNDERTAKE OWN SALES—NATURAL SODA REVIVES ON SOUNDER BASIS—CHLORINE DISPLACES BLEACHING POWDER AS PRICE DROPS TO  $3\frac{1}{2}\text{¢}$ —ELECTROLYTIC PLANTS IMPROVE CELL DESIGN, ADD NEW SALTS AND CHLORINE DERIVATIVES—WESTVACO BUYS WARNER AND FORMS UNITED CHEMICALS—EASTERN FIRMS BUILD WESTERN ELECTROLYTIC PLANTS—CHLORINE INSTITUTE FORMED.

**N**O ALKALI MAN, unless he were gifted with second sight, could have mapped in 1918 the course of his business during the next ten years. Most of the apparently reasonable expectations were upset by technical and commercial developments which, however logical they may now appear, were unforeseen at the time.

At the close of the war the production of both caustic soda and soda ash stood at high records: \* caustic, 513,363 short tons; soda ash, 1,390,628. With war demands gone and with every prospect of losing the abnormal export business to British makers, the threat of a crushing oversupply seemed imminent and inevitable. Vivid memories of a similar situation created prior to the war by the arrival of the Diamond Alkali Company as a producer, nourished a nervous apprehension that overwhelmed any optimistic confidence. Nobody dared to hope that increased domestic consumption could absorb the expanded output. But it did so, and by 1929 war-production records were broken in caustic soda by more than 50 per cent and in soda ash by 100 per cent. The unforeseen, phenomenal increase in the use of soda ash in the chemical, glass, soap, and paper industries, and of caustic soda in petroleum refining and notably in rayon manufacture,† would have resulted in an orderly expansion of the alkali trade had it not been for intraindustry competition of new products and new processes.

Most of the growth in alkali output during the war had been contributed by new or expanded electrolytic plants, and although during the twenties the six established ammonia-soda plants consistently supplied about 70 per cent of the caustic soda made in this country, the swing

\* For details of wartime production, see Vol. III, Appendix II; for 1923-29, Appendix XXIV.

† For consumption of caustic soda and soda ash by various principal industries, see Appendix XXV & XXVI.



toward electrolytic operations continued and accelerated.<sup>1</sup> The electrolytic producers recovered their confidence more quickly, yet they, too, had qualms when the end of hostilities shut off the war demand for chlorine. The enthusiasts among them had great faith in this versatile gas, but few anticipated how quickly it was to replace calcium hypochlorite as an industrial bleaching agent;\* or what a variety of chlorination processes were soon to be commercialized; or how the rayon industry's demand for highly purified caustic soda was going to strengthen their hands.

This alkali revolution produced some of the most profound changes initiated in the chemical industry during the eventful postwar decade. It demonstrated forcefully that even the most stable, big-tonnage chemicals—soda ash stands second only to sulfuric acid—are not immune to technological upsets and that no chemical, however low-priced and widely used, holds an indisputable position. It was a revolution that moved the solid inorganic foundations of the entire industry. As such, it shared with synthetic ammonia far-reaching effects among the basic heavy chemicals and in the newer, more showy field of organic synthesis. It was an early, striking instance of interprocess competition among chemicals, and it prompted numerous price revisions and encouraged the production of many new chemicals that loosed more and more inter-product competition.

The new competitive era, characterized by relentless, sometimes devastating struggles between processes and products, began during the latter half of the twenties and continued through the Great Depression right up to the outbreak of World War II. Accordingly, development of the electrolytic alkali process and the commercial advance of chlorine present us with convenient passkeys to many pages of chemical history, a comparatively simple example of the complexities of chemical competition involving the economic and technical problems of products and by-products, of alternative processes and substitute materials.

In the ammonia-soda process the primary product is soda ash from which the manufacturer obtains caustic soda by causticizing with lime. Operating economics places a premium upon continuous, full-scale production, nevertheless the manufacturer can at least control his output of caustic soda. During the 1920's, for example, when the consumption of ash more than doubled, expanding proportionately twice as fast as caustic, the ammonia-soda plants quite naturally adjusted by causticizing less of their primary product. It follows that the national requirements

\* By 1925 D. A. Pritchard was able to declare unequivocally that except in small-scale operations, the use of bleaching powder was obsolete in textile processing. See *Trans. Am. Electrochem. Soc.* 49, 36 (1926); for U. S. paper mills operating their own electrolytic plants, see Appendix XXVII.

for soda ash, which since the late twenties have not dropped much below 1,500,000 tons, are a backlog, an irreducible minimum below which the gross output of the ammonia-soda plants will not fall.\*

In the electrolytic process, on the other hand, chlorine and caustic soda are produced simultaneously in roughly equal amounts, and it is the demand for chlorine that dictates the production schedule. In both cases the secondary product, considered commercially, is caustic soda, and its sale is the focus of competition between the ammonia-soda process and the electrolysis of brine.<sup>2</sup>

In this competition the electrolytic process enjoys two fundamental advantages. Initial investment in plant is somewhat less and a unit of 10 tons daily capacity can be installed against the necessity of operations of 300 tons a day in the case of the ammonia-soda process. Furthermore, the output of an electrolytic plant may be easily varied by changing the voltage or by simply discontinuing certain batteries of cells so that the operation is more flexible. But these advantages carry their own disadvantage in that they have tempted large consumers of chlorine in the paper and textile industries to install their own electrolytic plants. This temptation was encouraged by the holders of electrolytic cell patents who went enthusiastically into the business of engineering and constructing such installations.<sup>3</sup> Every such producer-consumer not only took his own requirements for chlorine out of the market, but also added his by-product caustic. Often this was unceremoniously dumped on the market for whatever price it would bring.<sup>4</sup>

The Solvay Process Company was the first ammonia-soda manufacturer to meet the new situation directly by adopting the rival process. It installed high-pressure, steam-generating equipment, employing process steam to make virtually fuel-free electrical power, a neat engineering economy which had been in operation at the Dow plant since prewar. In this way Solvay subsidized an electrolytic production of chlorine by soda ash. The economics of combined operation of the two processes is so favorable that during the following decade all ammonia-soda manufacturers but one adopted it. By the outbreak of World War II only three of the nine ammonia-soda plants in this country (Solvay at Detroit and Mathieson at Saltville and Lake Charles) were not equipped to produce chlorine electrolytically.

\* "I think you have made a rash statement and I wonder if you really want to say this. It means, of course, soda ash production from ammonia plants, but the trend is the other way. . . . We electrolytic manufacturers think the last soda ash plant has been built and even go so far as to say that they will have to start shutting down one of these days. In the very nature of normal chlorine requirements there will be a surplus of caustic, part of which we foresee will be converted into ash to meet soda ash requirements. You will observe I, too, have indulged in rash prophecy. It will be interesting historically to leave your definite statement, and some years hence to prove whether or not it is true." (W. H. Dow, to author, May 6, 1946.)

The bull's-eye of competition in these realignments, the market for caustic soda,\* itself, came under a new influence during the twenties when the rayon manufacturers, whose requirements were large and growing rapidly, began demanding a purer product. The caustic soda produced in the diaphragm cell, then commonly used, was objectionable for rayon use because of excess sodium chloride, high iron content, and other impurities. Only the mercury cell consistently produced low-salt caustic. In the Castner cell the mercury acts as an intermediate electrode in place of a diaphragm. It forms an amalgam with the metallic sodium liberated from which the sodium reacts with water, forming a caustic soda solution with the evolution of hydrogen gas.<sup>5</sup> As originally designed this type of cell, which was controlled by the Mathieson Alkali Works, developed operating difficulties, chiefly mechanical. Its obvious advantage of a relatively salt-free production and reduction of other impurities simplified and cheapened the concentration of the caustic solution and promoted modifications.<sup>†</sup> The demand for purer caustic also spurred operators of diaphragm cells to an intensive study of this problem. In 1927 the Hooker Electrochemical Company began the commercial production of rayon-quality caustic<sup>6</sup> purified by the crystallation process developed by Albert Huntington Hooker<sup>‡</sup> and W. J. Marsh.<sup>§</sup> Still further improvements came about 1928 with the discovery of salt catchers and separators, working on the dialysis principle, and nickel-lined, forced-circulation evaporators to check corrosion and avoid iron pickup.<sup>7</sup>

Operators of the ammonia-soda process did not stand idly by. Their problem was different: not contamination by chloride, but the

\* "The electrolytic caustic soda for rayon was not of as high quality as that eventually developed by the ammonia-soda producers, but it sold at a lower price with the excuse that it was a by-product of the chlorine which had to be produced and shipped. This had a great deal to do with the building of electrolytic plants by the producers of soda ash." (H. S. Farleigh, to author, June 21, 1946.)

† Best known is the American Whiting cell (U. S. Pats. 951,228-9).

‡ A tangible, but unobtrusive part in the establishment and growth of the Hooker Electrochemical Co. was played by this charming, studious man who from its first organization by his brother, Flon H. Hooker, was plant mgr., later becoming tech. dir. "A. H." was born in Rochester, N. Y., Nov. 25, 1865, studied chem. at U. Rochester and Mass. Inst. Tech., and entered business without receiving a degree. Rochester awarded him an hon. M.S. in 1920. His first accomplishments were in the paint field where, starting as chem. with the Dighton Color Works, he closed this phase of his career as chief chem., Heath & Milligan Paint Mfg. Co., Chicago. In 1905 he came to Niagara Falls and from then till his death, Mar. 9, 1936, he was identified with Hooker Electrochemical developments. He filled many offices in technical societies and was for years a member of the N. Y. State Bd. for Licensing Professional Engrs. He was a man of wide, lively interests that ranged from gold to Indian archeology and was the author of many articles on pigments and alkalis. His sons, A. H., Jr., and Roger Wolcott, are respectively Western sales mgr. and vice-pres. and sales mgr. of the Co.

§ U. S. Pat. 1,733,879: filed Aug. 12, 1926, renewed Mar. 14, 1929, granted Oct. 29, 1929.

presence of such impurities as alumina, silica, and sulfates. They adopted a variety of chemical treatments designed to clean these up and so keep their caustic in a competitive position.<sup>8</sup> Both processes were contaminated by iron which was removed by chemical treatment and the use of nickel-lined evaporators.

While the comparatively new employment of caustic soda by rayon manufacturers and petroleum refiners accounted for most of the greater demand, the old channels in the paper and soap industries also widened and a revival of the mercerizing process in the cotton textile industry called for more caustic. The high price of crude rubber befriended the recently discovered process of reclaiming used rubber by means of caustic soda. This use increased 128 per cent in 1925 over the previous year's consumption.<sup>9</sup> The continued strength of the caustic market, combined with the astonishing doubling of the demand for soda ash, softened the blow of the loss of bleaching powder to chlorine and led to expansions of ammonia-soda plants. At the end of a three-years' program begun in December 1926, the Diamond Alkali Company had doubled the capacity of soda ash production at its Painesville plant to a daily potential up to 1,500 tons.<sup>10</sup> The Solvay Process Company in 1929 increased the soda ash capacity of its Detroit plant 200 tons a day and made a still further increase the following year, while at Syracuse production of caustic was expanded in 1929 and of ash in 1930.<sup>11</sup>

During this period of mounting intraprocess competition a commercial revolution revised the old methods of merchandising alkalies. The earlier alkali companies had initially placed their sales in the hands of well-established chemical merchants in New York, firms which had become thoroughly acquainted with the uses and users of chemicals while serving as American sales agents for the British manufacturers. Solvay appointed Wing & Evans its agents; Niagara Alkali, J. L. & D. S. Riker; and Michigan Alkali, Edward Hill's Son & Company. They thus acquired a trained sales staff and relieved their managements of many distribution and credit problems, enabling them to devote full energies to production.

Later-comers, with the exception of Diamond, adopted a modification of the same plan, Columbia naming Isaac Winkler & Brother of Cincinnati, and Mathieson, Arnold, Hoffman & Company of Providence, both experienced chemical houses whose principals had been financially interested in the launching of these new alkali enterprises. The general sales agents had in turn appointed established chemical jobbers at important industrial centers as their subagents for the local territory. For example, Wing & Evans for Solvay was represented in Philadelphia by Hollingsworth & Peterson, in Boston by Linder & Meyer,<sup>12</sup> in St. Louis and Kansas City by Whitelaw Brothers, while Hill sold Michigan alkalies

in Boston through the old importing and jobbing firm of E. & F. King and in Philadelphia through Ellis Jackson & Company.

This system of distribution was subjected to extraordinary strain during the First World War. Many old-established distributors faithfully supported the conservative price policies of the makers, nevertheless the whole jobbing trade, diluted as it was by interlopers attracted solely by the speculative opportunities, came into grave disrepute. The contradiction of interests was aggravated during the early twenties when the entire chemical price structure was under pressure from war surpluses and war-built capacities. Because of their crucial position as bread-and-butter items of the chemical trade, the alkalis became favorite weapons of the distributors in their local price battles for business.\* The market situation became serious for the manufacturers, encouraging them to protect their contract price schedules by taking over direct control of the less-than-carload sales. Various programs were adopted to achieve this change.

After breaking with Arnold, Hoffman & Company, Mathieson led the way to a completely controlled sales distribution system by opening its own sales offices and maintaining warehouse stocks in strategic cities. The youngest company, Diamond, never had a general sales agent but modified this plan of local representation. Under William G. Gundelfinger, local sales agencies were established which, while they handled Diamond alkalis exclusively, also sold other industrial chemicals. Important among these were W. F. George Chemicals, Inc., in New York, headed by an old Hooker man, William F. George;† Consumers Chemical Company of which Fred C. Wolters, Jr., was president, in Philadelphia; the Benner Chemical Company, managed by S. R. Benner in Chicago; and Marble-Nye Company in Boston.

Among the older companies, the first significant change was the dissolution of J. L. & D. S. Riker upon the retirement of its president, Charles L. Riker, as of December 31, 1922. The sales agencies of this old firm of chemical merchants, established in 1860 by John L. and Daniel S. Riker, were taken over by their trusted employee, Joseph Tur-

\* See Chap. 2.

† Thanks to the knowledge and tact of "Billy" George, this organization became a famous school for future sales executives: Geo. S. Cooper, later vice-pres. of Diamond; Ben P. Steele, sales mgr. of Penn Salt; and Charles V. Douglas, N. Y. mgr. of Diamond. George, who was born in Lockport, N. Y., Oct. 28, 1889, started on the eng. staff of the Niagara Falls Power Co. and joined Hooker as purchasing agent in the Construction Dept., moving shortly to the N. Y. sales office. He organized his own company in 1919 and remained its active head till in 1928 he became partner in Haynes & George Co., publishers of *Chem. Ind.* After that journal was sold in 1939, he rejoined Hooker in charge of sales in the Eastern territory.

ner,\* who formed a partnership with his son-in-law, Walter D. Merrill.† Shortly after the close of the war the Solvay Process Company took over Wing & Evans, and although the historic name was kept for some years, the organization became literally the Solvay sales staff, in charge of Horace G. Carrell.<sup>13</sup> While sales representation continued through many of the old local distributors, Solvay took steps to consolidate the organization by opening its own sales office in 1923 in Cincinnati,<sup>14</sup> under the management of Phillip W. Drackett, Jr.‡ Two years later Solvay acquired the old firm of Whitelaw Brothers which since 1881 had carried on a general chemical jobbing business in St. Louis and Kansas City under Malcolm and Ralph W. Whitelaw. The Whitelaw agencies outside of alkalies were taken over at this time by G. S. Robins & Company § of St. Louis.<sup>15</sup> On January 1, 1924, another old firm of chemical merchants disappeared when Edward Hill's Son & Company became the Sales Department of the Michigan Alkali Works, with Eugene M. Taylor as sales manager.<sup>16</sup>

\* While this transformation in merchandising was of paramount importance, there were other developments in the commercial arena. In 1923 Wing & Evans, as agents for Solvay, announced a change in the method of quoting soda ash and caustic soda from the basis of New York and Liverpool tests to actual tests, and effective July 1, quotations on these chemicals were made on the basis of 100 pounds as shipped.<sup>17</sup> This simplification was quite promptly adopted by all sellers.

\* Sharp as a splinter of glass, honest as a balance scale, Joe Turner was the very epitome of the vanishing breed of chemical traders. He knew every card in the pack, having an amazing knowledge of chemical costs, freights, grades, and uses, backed by an uncanny insight in the vagaries of chemical supply and demand. Finally he knew the buyers, not only "by their first names," but what were their requirements and their foibles. As a lad of 15 Turner went to work for Riker. By 1912 he was gen. mgr., and during the war he served on the Chem. Warfare Bd., refusing a Colonelcy. He was born in England and died at his home in Ridgewood, N. J., Nov. 17, 1935, at the age of 67.

† A West Point graduate, Merrill resigned shortly after being commissioned to enter the Turner firm. He became sales mgr. in 1931; gen. mgr. in 1932; and head of the firm on Turner's death. He re-entered the Army in World War II, terminating his service as a Lt. Col.

‡ At this time his brother, Harry R. Drackett, who had been partner and sales mgr. of P. W. Drackett & Sons Co., also branched out for himself, establishing the Drackett Chemical Co. and the Drackett Products Co., makers of household and industrial chemical specialties.

§ A jobber of integrity and vision, George Stanley Robins was a constructive factor in the Midwest chemical trade and his early death, Nov. 21, 1936, was widely felt. He first became a salesman of industrial chemicals for the Churchill Drug Co., soon moving to A. S. Barada & Co., and in 1917 becoming vice-pres. of Thompson-Munro-Robins Chemical Co. In 1923 he took over the St. Louis office as his own business, while his partner, Chas. T. Thompson, formed the Thompson-Hayward Chemical Co. at Kansas City. Robins, who was born in Brooklyn, N. Y., Oct. 1, 1892, was educated in chemistry (B.S., 1913) at Rutgers, where he won a Phi Beta Kappa key. He was chmn., St. Louis Sect., Am. Chem. Soc., 1927-28.

The household lye business, the sale of packaged caustic soda particularly for the homemaking of soap, continued to decline and at the same time to pass more and more into the hands of primary manufacturers of alkalis. In 1922 S. Wander & Sons Chemical Company, one of the largest of the lye firms, with a packing plant at Albany, was reorganized.<sup>18</sup> During 1926 Diamond Alkali, which had increased its production of sodium bicarbonate,<sup>19</sup> established the subsidiary, Buckeye Soda Company, at Painesville, to make sal soda and as an outlet for packaging and merchandising sal soda, baking soda, and lye to the retail trade. That same year, the Pennsylvania Salt Manufacturing Company, always an important factor in the packaged lye field, bought the Eagle Lye Works of Milwaukee and transferred the operations to the Wyandotte plant near Detroit.<sup>20</sup>

During this period there was much agitation to compel the labeling of packaged lye as a poison. In fact the year 1921, when 41 state legislatures were in session, was branded an "open season" for bills of this character.<sup>21</sup> In 1929 the Food, Drug and Insecticide Administration had record of 15 firms engaged in this large-scale packaging and marketing of lye, sold under their own brands or labeled in the name of local distributors, both wholesale and retail.<sup>22</sup>

Production of alkalis from natural brines in the Western states, which had sprung up during the war and languished afterwards, began to revive on a sounder basis. In 1927 the Clark Chemical Company brought into operation a plant at Owens Lake, California, for the manufacture of caustic soda from trona by the Mount continuous process, with an output of 30 tons a day, part of which was marketed in liquid form to the petroleum refiners.<sup>23</sup> Production of the soda ash went further and was more successful, and in 1929 five West Coast companies—Inyo Chemical, Pacific Alkali, Natural Soda Products, West End Chemical, and Washington Soda Products—were all active producers.<sup>24</sup>

Though no alkali, chlorine was by now so inseparably associated with caustic soda in the electrolytic process that it became a part—in some ways the crucial part—of this branch of chemical manufacture, and in research, in production, and in sales its influence grew. The postwar supercapacity precipitated a headlong drop in prices: the open-market quotation for liquid chlorine in cylinders in carload lots of 15 cents a pound at the signing of the Armistice was 6 cents six months later. This price rebounded during 1920-21, but the middle of 1922 it declined to 5 cents, never again to go higher than 6.\* This drastic decline paced the interproduct competition with bleaching powder. Both chemicals were overproduced; neither can be stored for any length of time economically. The climax came in 1923 and the victory was won quickly by chlorine.<sup>25</sup>

\* For chlorine prices, 1923-29, see Appendix IV.



*Chemical Industries*

JOHN J. WATSON



JAMES A. BARR



SYDNEY H. THOMSON



CHESTER A. FULTON





JOSEPH TURNER



E. M. ALLEN



EDWARD A. TAYLOR



WILLIAM B. THOM

By 1926 bleaching powder had been virtually displaced in the pulpwood and textile industries,\* and of 6,000 water-treating plants fewer than 25 were still using hypochlorite, the others having changed to liquid chlorine.<sup>26</sup>

The price of chlorine was now a third of what it had been prewar, a situation which, as John A. Kienle of Mathieson pointed out, was ruinous to the makers of bleaching powder.<sup>27</sup> But the end was not yet. From 5¾ cents at the beginning of 1927, the price in tankcars dropped to 3½ cents. Ammonia-soda makers had turned to the electrolytic process, the production of Solvay having come on the market in 1927,<sup>28</sup> and Diamond, and Pennsylvania Salt having announced their intention to build electrolytic plants. The Penn Salt plant was projected for the West Coast where Hooker was already building a new electrolytic plant.

Every electrolytic producer frantically sought ways and means of slicing his costs. In the case of the Hooker Electrochemical Company "during the 1920's stress was primarily laid upon electrochemical and engineering developments of cells and upon improving the economies and efficiencies of the company's operations,"<sup>29</sup> work that achieved the deposited diaphragm and made a good start towards development of the Hooker Type S cell.<sup>30</sup> Such intensive, industry-wide researches could not but bring results. In 1924 a sodium-chlorine cell was patented by James C. Downs and assigned to the Roessler & Hasslacher Chemical Company.† In 1927 electric fusing of caustic soda was accomplished by the Joseph Riordan Pulp Corporation in Quebec on a commercial scale, making an estimated saving of \$10,000 annually.<sup>31</sup> In May the following year, the Solvay Process Company undertook commercial production of potassium hydroxide by electrolysis of potassium chloride.<sup>32</sup> The Isco Chemical Company, subsidiary of Innis, Speiden & Company, which had built an electrolytic chlorine plant at Niagara Falls under the management of Eben C. Speiden,‡ and had been producing caustic potash

\* Authorities differ in their estimates: E. D. Kingsley stated the production of liquid chlorine was 50,000 tons in 1925 (against about 3,000 tons in 1914); R. T. Baldwin placed it at 65,000 tons in 1926; D. A. Pritchard, at 46,000 tons in 1926 (including Canada). Of this total, Kingsley estimated 70% went to paper and pulp; Baldwin, 50%; Pritchard, 66%. Estimates of consumption in textiles were: Baldwin, 15%, Pritchard, 22%; in sanitation, Baldwin, 15%, Pritchard, 10%. Baldwin also estimated that 19% of the chlorine produced in 1926 went into the manufacture of organic and inorganic chemicals. [See Kingsley, *Chem. Mkts.* 19, 95 (1926); Pritchard, *Trans. Am. Electrochem. Soc.* 49, 38 (1926); Baldwin, *Chem. Met. Eng.* 34, 372 (1927).]

† U. S. Pat. 1,501,756: filed Aug. 18, 1922, granted July 15, 1924.

‡ Scion of the well-known chemical family, which, like the E. C. Klipsteins, came from the village of Marshall, Va., Eben Childs Speiden went to Cornell (M.E., 1904), then joined the Acheson Graphite Co. where in the next 10 yrs. he advanced from plant foreman to gen. mgr. sales. In 1915 he became vice-pres. and gen. mgr. of Isco, and in 1917 dir. and vice-pres. of the parent corp., Innis, Speiden & Co. In 1924, when the

ever since 1918, added potassium carbonate in 1926,<sup>33</sup> building a special plant unit for its production.\* Inevitably cell design and operation came in for scrupulous study. There were numerous improvements and some companies switched from one type to another, as when the Niagara Alkali Company in 1928 replaced the Billiter with an improved Gibbs cell.<sup>34</sup>

But there is always an irreducible minimum below which the costs of any process cannot be reduced. Raw material values, the theoretical limits of the chemical reactions involved, and especially in the electrolytic process, power costs, may only be changed by changing the process itself. The closest possible approach to minimum cost was obviously of vital concern to each company, yet for the industry as a whole, with chlorine obviously overproduced, the over-all solution could only come by increasing its consumption. Having captured the bleaching and sanitation fields, additional outlets lay in the chemical uses of chlorine. Accordingly, most producers were forced into another line of research to discover new applications.

Again developments came so quickly that by 1928 it was estimated<sup>35</sup> these chemical uses had become the single greatest consumer of chlorine.† Though not widely heralded, these chlorine developments were among the most interesting and valuable of these years. The first, most obvious advance was the direct use of chlorine in the manufacture of a great number of chemicals: chlorobenzene, carbon tetrachloride, chloroform,

Chlorine Inst. was organized, he was elected its first pres., a post he filled with tact and energy until 1933.

\* "To me this statement would convey the impression that the Solvay Process Co. was the first to begin production of potassium hydroxide in 1928 and that Innis, Speiden had been producing it since 1918 and was also the first to produce potassium carbonate in 1926. This does not jibe with the facts which are that the Niagara Alkali Co. was the sole producer of caustic potash as early as 1901 and that Innis, Speiden & Co. during that period, and perhaps prior to that period, imported the German material into this country but never began the manufacture until many years later. I do not think Innis, Speiden began producing carbonate in 1926, but also imported this material from Germany. The first commercial production of carbonate of potash in U. S.—made from chemical muriate—was in 1934 by the Niagara Alkali Co." (S. W. Jacobs, to author, Apr. 29, 1946.)

† "It was a long time before 1928, but I do not believe you have any way of showing that from the published record. I am thinking of our own production: as early as 1905 we were using chlorine as an intermediate in the manufacture of other products and our consumption for this purpose steadily increased without appreciably losing chlorine sales tonnage. We discontinued the manufacture of bleaching powder around 1910-12 and had by that time absorbed enough chlorine in other products that we continued to enlarge our chlorine capacity. I would not wonder we might claim to be the pioneer in this use of chlorine, but prior to 1930 we were always careful not to publicize any more than we could help, the operations of our plant, and from the published record I am sure you will find very little of this information as far as Dow is concerned." (W. H. Dow, to author, May 6, 1946.)

aluminum chloride, benzoic acid and the benzoates, ethylene glycol, ferric chloride, and hydrochloric acid.

From the point of view of the producer, the ideal use of chlorine is in organic syntheses where it does not appear in the end product and where the consumption of an equivalent amount of caustic soda is required, yielding by-product sodium chloride. Unfortunately this use was then uncommon. Where chlorine becomes a part of the end product, hydrochloric acid is frequently produced as a by-product. How to dispose of this acid is a troublesome question. It cannot be dumped or poured into the river, nor can it be easily, economically converted into its components, hydrogen and chlorine, for re-use. It must therefore compete with the cheaper, more familiar, more versatile sulfuric acid. The economics of muriatic acid still remains a knotty problem of the chlorine industry.

During the twenties new chemical uses of chlorine came thick and fast, multiplying in all directions like the twigs of a rock maple. A profitable outlet for by-product hydrogen from the chlorine cells was found in 1923 in the production of synthetic ammonia. This was followed next year by the preparation of sulfuryl chloride, of high-test calcium hypochlorite, and of ethyl chloride from ethyl alcohol and hydrochloric acid. This year ethyl cellulose, the plastic, and tetraethyl lead, the anti-knock, both appeared,<sup>36</sup> though the former did not become commercially important till the middle thirties. In 1925 new chlorinated solvents were offered to the dry-cleaning trade; phenol was prepared from monochlorobenzene; hypochlorite began to be used for sweetening gasoline; chlorinated rubber was made.

Between 1926 and 1929 chemical applications of chlorine increased even more rapidly. Chlorination of ethylene and pentane started in earnest, producing ethylene glycol, ethylene dibromide, ethylene chlorohydrin,\* and the amyl compounds, while the chlorination of naphthalene gave a new and useful series of synthetic waxes. From monochlorobenzene an exceedingly interesting heat-exchange agent, diphenyloxide, was prepared by Dow whose research staff also perfected a process of making aniline by treating monochlorobenzene with ammonia. New uses for chlorine derivatives also developed. Aluminum chloride was sug-

\* "During the First World War we produced ethylene chlorohydrin at Midland for mustard gas operations. Later we attempted to develop a market for it, but did not do so. At the same time we developed ethylene glycol and tried to sell it to du Pont for making explosives, but could not get them interested. Another firm made a great success of it, so you see we made a big mistake there. However, that sort of thing happened to everybody when someone else saw a use for a product the first man did not see, and the company that puts it across is certainly entitled to both credit and success." (W. H. Dow, to author, May 6, 1946.)

gested as a carbonizer of wool\* and the glycol ethers as cellulose solvents. In 1927 glycerin was synthesized by the hydrolysis of allyl chlorohydrin. The vinyl resins came into their own and vinyl chloride was first used as photographic film. Direct use of chlorine as a bleaching agent was also expanded in the bleaching of kraft paper and with caustic soda in the de-inking of newsprint. Continued growth in the production of acetate rayon consumed more and more sulfur chloride.

Twice during this period the American Electrochemical Society held meetings devoted largely to the problems of the electrolytic alkali industry. As its forty-ninth meeting, Chicago, April 22-24, 1926, there was a full day's lively session on the utilization of chlorine. Mother Nature erred grievously in her formula for salt, as one of the members aptly phrased it, for had it been  $\text{Na}_2\text{Cl}$ , there would have been no topic for discussion and no overproduction problem for the industry to solve.<sup>37</sup> The Pittsburgh meeting in 1929 devoted its attention to the electro-organic chemical industry. At a special session presided over by the president, Francis C. Frary,<sup>†</sup> the rapidly expanding importance of this field was reviewed and the advantages of electrical over chemical processes, especially in the case of controlling output and purity of product, were made clear. Highly practical papers were read on the electrolytic preparation of benzoic acid, benzaldehyde, 2, 4-diaminophenol, phenylhydrazine, and anthraquinone.<sup>38</sup>

Closely akin to the electrolytic alkali developments were the developments in hydrochloric acid. About 1920 at Batavia, New York, Edward Cyrus Walker, with the consulting assistance of H. M. Goodwin,<sup>‡</sup> perfected for the Genesee Chemical Company an electrolysis of hydrochloric acid to produce a high-grade perchloric acid,<sup>39</sup> and achieved

\* "The Merrimac Chemical Co. introduced aluminum chloride on a large scale in the textile mills of Lowell, Lawrence, and Haverhill, under the name of 'Carbonizer' in 1890. It was made by dissolving Bayer process hydrate of alumina in muriatic acid, which gave a solution about 36° Bé. shipped in carboys and used in carload lots." (H. Howard, to author, May 7, 1946.)

† Perkin medalist, 1945; pres. of both Am. Electrochem. Soc. and Am. Inst. Chem. Engrs.; many yrs. councilor of the Am. Chem. Soc.; this distinguished research dir. of the Aluminum Co. (1919 to date) has been a great contributor to applied metallurgy, electrochemistry, and chemical industry. Frary was born in Minneapolis, July 9, 1884, and attended the state U. where, after a yr. at U. Berlin, he won his Ph.D., 1912, and where he taught until 1913. Before coming to the Aluminum Co., he was with Oldbury Electro-Chemical and served during the war as Capt. in Ordn. and Maj. in Chem. Warfare Serv. He has also been awarded the Pittsburgh award of the Am. Chem. Soc., 1927, and the Acheson medal of the Am. Electrochem. Soc., 1939.

‡ Dean of the graduate school of Mass. Inst. Tech. from 1926 till his retirement in 1940, Harry Manley Goodwin carried on lifelong studies in theoretical and applied electrochem. in the labs. of his Alma Mater (B.S., 1890). He became an instructor, after earning his Ph.D. at Leipzig, 1893, and headed the Electrochem. Dept. in 1906. Walker, associated with the Genesee Co., was one of Goodwin's graduate students, 1915-17, when he received his Eng.D.

commercial production. Under the aegis of Henry Howard, who in 1920 had left the Merrimac Chemical Company as executive in charge of research and development, and Edward A. Taylor,\* Grasselli's chemical director, an electrical distillation process was worked out for the manufacture of chemically pure hydrochloric acid.<sup>40</sup> The purposes of this research were not only to produce an exceptionally pure acid but also, by employing electrical energy in place of fuel, to reduce operating costs and breakage, and to develop a process and apparatus that might also be applied in the manufacture of nitric acid.

These swift-moving electrolytical developments became a veritable race, so that although chlorine output continued in excess of demand, company after company increased its chlorine capacity. Conspicuous and disconcerting was the installation of electrolytic plants by two of the old ammonia-soda operators, Solvay at Syracuse in 1927 and Diamond at Painesville, Ohio, in 1929.<sup>41</sup> In 1926 the Solvay Process Company took over the plant of Semet-Solvay which had been producing, besides coal-tar intermediates and crudes, electrolytic caustic and chlorine, hydrochloric acid, and sodium nitrite, and placed the sale of caustic and liquid chlorine in the hands of the Solvay Sales Corporation.<sup>42</sup> Diamond Alkali Company,† which in 1929 reincorporated with a capital of \$18,500,000 in Delaware,<sup>43</sup> brought its electrolytic plant on steam in February.<sup>44</sup> Mathieson Alkali Works in 1926 set aside \$500,000 for the specific purpose of modernizing equipment at Niagara Falls, Saltville, and in the Newark, New York, plant of its subsidiary, the Commonwealth Chemical Corporation.<sup>45</sup> The same year it took over the Fields Point Manufacturing Company with an electrolytic plant just below Providence, Rhode Island.<sup>46</sup> Daniel Townsend continued as manager of the operation, and in addition took over general supervision of Mathieson sales in the New England territory.

In 1927 William B. Thom‡ negotiated for the Westvaco Chlorine Products Corporation a chlorine sales contract with the Carbide and Carbon Chemicals Corporation that was of more than passing interest. From its Charleston, West Virginia, plant, Westvaco undertook to supply for ten years the chlorine requirements of the adjacent "C & C" plant for the manufacture of ethylene glycol and other synthetic organic

\* Taylor was born in Cleveland, Sept. 4, 1889, and graduated from Case, B.S., 1911. After a couple yrs. with Chisos Mining Co., he came to Grasselli as anal. chem., working up to chem. dir. and continuing in this key post after the amalgamation with du Pont.

† Successor to the corp. of the same name, inc. in W. Va., Mar. 1902.

‡ Thom, typical of the new generation of chemical executives who rose from the ranks during and following World War I, has spent his entire business life with the same co., starting as a bookkeeper with the Warner Chemical Co. in 1915. He won the confidence of Dr. Warner and served increasingly as his asst. and deputy, succeeding upon his death to pres. He was born Oct. 8, 1891, at Buffalo, Wyo., and graduated from U. Mich. (A.B., 1915).

chemicals. On the basis of these growing requirements the Westvaco plant shortly became the largest chlorine producer in the world. Simultaneously Thom, then in his early thirties, engineered the transformation of the Warner family interests into a modern holding corporation. His first step was the incorporation of the Westvaco Chlorine Products Corporation \* in Delaware with a capitalization of \$1,700,000.<sup>47</sup> A year later Westvaco absorbed the Warner Chemical Company, acquiring all of its stock for 15,699 shares of 7 per cent preferred of Westvaco and \$589 in cash.<sup>48</sup> The third Warner interest, the Monarch Chemical Company, manufacturers of baking powders, with factories in Brooklyn, Chicago, and San Francisco, was also consolidated in the summer of 1929, by the purchase of 97 per cent of its common stock.<sup>49</sup> That autumn the Barium Products, Ltd., of Modesto, California, and the Peroxide Manufacturing Company of San Francisco, producers respectively of barium salts and hydrogen peroxide, were purchased,<sup>50</sup> together with the Curtin-Howe Corporation, specializing in wood preservative chemicals. Early in 1929 United Chemicals, Inc., was organized † to acquire the common stock of Westvaco and its subsidiaries and to provide an investment fund for other properties, foreign and domestic, engaged in chemical industry. The company was set up with a \$6,000,000 cash balance and 102,000 shares of common stock of Westvaco received in exchange, share for share, of its own common stock.<sup>51</sup>

When in 1916 the Great Western Electro-Chemical Company turned on the power in the first West Coast electrolytic plant, the apparently insoluble problem of the management had been to sell its chlorine. Within ten years the market picture had changed completely. By 1924 the chlorine capacity of the plant had been increased to 35 tons a day, practically all of which was liquefied and sold to the paper industry of the Pacific Northwest.<sup>52</sup> In fact, so tempting was this growing market and the favorable hydroelectric rates in the region, that two Eastern companies invaded this field in 1928. The Pennsylvania Salt Manufacturing Company, which had a chlorine plant at Wyandotte, Michigan, and which three years before had bought the plant of the Michigan Electrochemical Company at Menominee, Michigan,‡ incorporated the

\* Officers at this time were Wm. B. Thom, pres.; Wm. D. Patten, vice-pres., research; John A. Chew, vice-pres., sales; A. M. Pitcher, vice-pres., production; M. E. Gilbert, secy.-treas.

† Directors were Matthew C. Brush, pres., American International Corp.; Clifford B. Ewart, pres., Taylor, Ewart & Co.; H. Hobart Porter of Sanderson & Porter; Edwin A. Potter, Jr., vice-pres., Guaranty Trust Co.; Wm. B. Thom, pres. of United. Other officers were A. M. Pitcher and F. W. Wright, vice-pres.; M. E. Gilbert, secy.-treas.

‡ Complaint against Perm Salt that the purchase of Michigan Electrochemical was in violation of the Clayton Act was dismissed by the Fed. Trade Comm. [See *Chem. Mkts.* 24, 268 (1929).]

wholly owned subsidiary, the Tacoma Electrochemical Company,\* for \$1,000,000.<sup>53</sup> On a 40-acre tract adjoining the Hylebos Waterway, construction was begun in June 1928 and the plant brought into operation early the next year. Even before this installation was completed, the Hooker Electrochemical Company built an electrolytic plant also at Tacoma. It involved an investment of over \$1,500,000 and came into production February 4, 1929, with an output of 26 tons of chlorine daily from an improved type of the Townsend cell.<sup>54</sup>

Thus by 1929 the electrolytic industry had spread from its birthplace in Maine to the Pacific Coast, reaching every section except the Deep South, but already blueprints had been drawn for new installations soon to be made in Louisiana and Texas. Direct use of liquid chlorine had become standard practice in bleaching operations, in water and sewage disinfection, and in many chemical processes. It had been greatly encouraged by the order of the Interstate Commerce Commission allowing the same rating and privileges for the multi-unit car of ten, one-ton cylinders as for the full tankcar.<sup>55</sup> Recognizing that shipments of this dangerous gas involved common responsibilities and appreciating that the cultivation of new uses for chlorine might be furthered by prompt dissemination of reliable technical data, a group of leading electrolytic manufacturers organized the Chlorine Institute in March 1924, and incorporated it in Connecticut. Eben C. Speiden of the Isco Chemical Company was elected president of the nonprofit organization, and Robert T. Baldwin † was named secretary and executive head. Research projects were immediately launched in two important spheres, the chlorination of sewage and the bleaching of cellulose.<sup>56</sup>

At a Congressional hearing in 1929, Edwin M. Allen, president of Mathieson, neatly summarized the position of alkalies in the chemical economy of the country when he pointed out that their products were not only essential to virtually every industry in the United States, but that in world trade they bore the brunt of the fight for foreign chemical markets.<sup>57</sup> He added that the industry was giving employment to 42,000 people; that it represented a capital investment of over \$205,000,000; that it gave American railroads 7,700,000 tons of freight each year.

\* Name changed in 1928 to Pennsylvania Salt Mfg. Co. of Washington.

† A distinctive public service has been rendered the entire chemical industry by "Bob" Baldwin. Since its inception he has guided the destinies of the Chlorine Inst., one of the most constructively useful of the many trade and technical organizations, and he has also served in a similar executive capacity for the Milk Sugar Inst. since 1927 and the Assoc. Consulting Chem. & Chem. Engrs. since 1931. He has been for years treas. and dir. of the Am. Chem. Soc. and secy. of the Chemists' Club (N. Y.). Since 1927 he has been consulting ed. of *Chem. Ind.* and since 1936 a member of the Tankcar Comm., Assoc. Am. R. R.'s. Baldwin was born in Wilmington, Del., May 31, 1882, and went to work for the old cotton firm of Jos. Bancroft & Sons Co. in 1899. In 1918 he became a civilian employee of QMC and Gen. Staff of the U. S. Army, at the end of the war becoming asst. to the pres. of National Aniline.



## REFERENCES

1. *Ind. Eng. Chem.* 23, 393 (1932); for alkali producers, 1929, see Appendix XXVII.
2. H. Ahlquist, *Ind. Eng. Chem.* 27, 627 (1935); D. Aronson, *Chem. Ind.* 50, 324 (1942); *Rogers' Industrial Chemistry*, 6th ed., I, 5.
3. Aronson, *op. cit.*
4. J. A. Kienle, *Chem. Met. Eng.* 35, 46 (1928).
5. J. W. Richards, *Electrochem. Ind.* 1, 11 (1902).
6. Co. memo to author; P. S. Brallier, *Ind. Eng. Chem.* 33, 155 (1941).
7. Brallier, *op. cit.*
8. Aronson, *op. cit.*
9. *Chem. Met. Eng.* 33, 48 (1926).
10. Co. memo to author.
11. *Ibid.*
12. *O.P.D. Repr.* 74 (Jan. 1, 1923).
13. *Drug Chem. Mkts.* 17, 625 (1925).
14. *Ibid.* 12, 1040 (1923).
15. *Ibid.* 17, 1671, 1801 (1925).
16. *Ibid.* 16, 17 (1924).
17. *Ibid.* 12, 1551 (1923).
18. *Ibid.* 10, 399 (1922).
19. Co. memo to author.
20. *Moody's Manual of Investments, Industrials*, 1940.
21. *Drug Chem. Mkts.* 16, 1266 (1925).
22. *Ann. Rept.* 1929, p. 15.
23. P. D. V. Manning, *Chem. Met. Eng.* 34, 17 (1927).
24. *O.P.D. Repr.* 49 (Apr. 7, 1930).
25. *Drug Chem. Mkts.* 14, 853 (1924).
26. *Rogers' Industrial Chemistry*, 5th ed., p. 74.
27. Kienle, *op. cit.*
28. Aronson, *op. cit.*
29. Co. prospectus, Feb. 16, 1944, p. 5.
30. Co. memo to author.
31. *Chem. Mkts.* 21, 423 (1927).
32. Co. memo to author.
33. *Ibid.*; *Chem. Ind.* 36, S54 (May 1935).
34. Co. memo to author.
35. Kienle, *op. cit.*
36. Brallier, *op. cit.*
37. *Chem. Met. Eng.* 33, 274 (1926); orig. papers, *Trans. Am. Electrochem. Soc.* v. 49 (1926).
38. *Chem. Met. Eng.* 36, 602 (1929); orig. papers, *Trans. Am. Electrochem. Soc.* v. 56 (1929).
39. H. M. Goodwin and E. C. Walker, III, *Trans. Am. Electrochem. Soc.* 40, 165 (1921).
40. C. M. Hoff, *ibid.* 53, 279 (1928).
41. Brallier, *op. cit.*
42. Co. memo to author; *Chem. Mkts.* 19, 1251 (1926), 21, 643 (1927).
43. *Chem. Mkts.* 24, 73 (1929).
44. *Ibid.* 23, 330 (1928); *O.P.D. Repr.* 50 (Aug. 20, 1928); Co. memo to author.
45. *Drug Chem. Mkts.* 18, 1206 (1926).
46. *Ibid.* 1007.
47. *Chem. Mkts.* 19, 400 (1926); 20, 1, 450 (1927).
48. *Moody's, op. cit.*
49. *Chem. Mkts.* 25, 181 (1929).
50. *Ibid.* 405.
51. *Ibid.* 24, 299 (1929); *Poor's Manual of Industrials*, 1930.
52. W. Herschkind, *Chem. Met. Eng.* 38, 660 (1931).
53. *Ibid.* 34, 773, 783 (1927), 40, 177 (1933); *Chem. Mkts.* 21, 784, 785 (1927).
54. Co. memo to author; *Chem. Mkts.* 23, 161 (1928), 24, 154 (1929).
55. *O.P.D. Repr.* 22 (Nov. 23, 1925); *Drug Chem. Mkts.* 14, 405 (1924), 17, 1463 (1925).
56. E. D. Kingsley, *Chem. Met. Eng.* 32, 86 (1925).
57. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. I, Jan. 7, 1929, p. 841.

## Chapter 9

### OTHER INDUSTRIAL CHEMICALS

SYNTHETIC PRODUCTS UPSET *status quo*—SALT CAKE IN PRIMARY PRODUCTION—GREATER OUTPUT OF SODIUM SALTS FOLLOWS NEW USES—CHEAP ALUMINUM CHLORIDE IN PETROLEUM REFINING—BARIUM PIGMENTS FORCE REORGANIZATION IN BARYTES—DOW PERSEVERES IN MAGNESIUM FROM BRINE—MAGNESITE RECOVERS FROM FOREIGN DUMPING—CHROME PLATING MAKES CHROMIC ACID AN INDUSTRIAL CHEMICAL—ALUMINUM COMPANY PRODUCES ARTIFICIAL CRYOLITE.

THAT CONVENIENT CLASSIFICATION into heavy and fine chemicals was fast becoming meaningless. Products of virtually C.P. purity were increasingly sold by the ton; borax was being used by the glass industry as an industrial alkali; methylene blue was being prescribed by physicians; bromine shifted from sedatives and photographic reagents to anti-knock fluid; calcium phosphate of baking powder grade was classed as a heavy chemical by a British customs referee.<sup>1</sup> Whether based upon quality or quantity or use, the old distinctions were so blurred that the terms no longer served as clean-cut definitions.

The coal-tar group, divided into dyes and medicinals, remained distinctive. But other synthetic organic compounds were entering into many industrial applications, confusing any effort neatly to docket chemical products upon the basis of chemical origin. Alcohol distilled from fermented starches or sugar, one of man's earliest chemical discoveries, met in competition ethanol, synthesized from ethylene. Butanol promptly met the same fate. Ethylene glycol, herald of a whole army of aliphatic compounds, appeared. The three great products of the destructive distillation of hardwood—methanol, acetone, and acetic acid—were all synthesized upon a commercial basis. Carbon tetrachloride and chloroform became cheap industrial reagents in abundant supply, while whole families of benzene-ring compounds offered new tools to chemical and processing industries. These invading organic synthetics profoundly upset the *status quo* of industrial chemistry, so that reconversion to a peacetime basis, which occupied the industry during the early twenties, was followed by complicated readjustments demanded by this burst of technical progress.<sup>2</sup>

The effects of this trenchant revolution reached from the top of the heavy chemical list to the bottom. Synthetic ammonia replacing sodium

nitrate in the manufacture of nitric acid greatly cut down the supply of by-product salt cake. It would be hard to imagine a more stolid waste product than this crude sodium sulfate, or one less apt to incite a market riot. But curtailment of salt cake supplies was interwoven with the always thorny problem of surplus hydrochloric acid and it came at a time when demand was growing in the expanding kraft paper industry of our Southern states.\*

Reacted with sulfuric acid, common salt (sodium chloride) yields sodium sulfate while Chile saltpeter (sodium nitrate) yields sodium bisulfate, i.e., salt cake and niter cake, respectively. Salt cake is the first step in the production of soda ash by the Leblanc process; niter cake is the by-product in nitric acid manufacture. The Leblanc process having been superseded by the Solvay process, salt cake was prepared by reacting niter cake with more salt, getting hydrochloric acid as the joint product. During the war, production of nitric acid for explosives accumulated a surplus of niter cake † which was consumed in this production of salt cake and Glauber's salt, with a marked saving of the then-scarce sulfuric acid.

Once this war surplus was used up, however, and nitric acid makers began to discard the sodium nitrate-sulfuric acid reaction for ammonia oxidation, a shortage of salt cake followed. This concerned our pulp and paper industries whose demand for salt cake exceeded the national requirements for its joint product, hydrochloric acid. The chemical economics of this situation was complicated by considerable quantities of by-product hydrochloric acid from the growing chlorination of hydrocarbons. Though hobbled by this by-product acid, the deliberate, primary production of salt cake grew and even fostered the invention of an improved American furnace by N. A. Laury,‡ which has become a serious rival of the Mannheim muffle-type furnace.

Escape from the hydrochloric acid dilemma was sought in the natural deposits of sodium sulfate scattered over the dry areas of California, New Mexico, Nevada, Utah, Oregon, and Washington. These were actively exploited during the twenties. An important factor was the Ozark Chemical Company,<sup>3</sup> organized with a capitalization of \$500,000 in 1925, with W. N. Smith as president and Park Kelley,<sup>§</sup> general manager. One of the first of these postwar soda projects was the Southern

\* Kraft pulp manufacture requires from 150 to 475 lb. of salt cake per ton of pulp, with an average of about 250 lb. For production of salt cake and related sulfates, natural and refined, see Appendix XXVIII.

† See Vol. III, p. 67; also Laury, *Hydrochloric Acid and Sodium Sulfate*.

‡ U. S. Pat. 1,435,930 (1922).

§ Born in Indiana, Apr. 2, 1886, Kelley attended U. Wis. 1905-7, and was with the Vinegar Hill Zinc Co. for 13 yrs., resigning in 1923 to become a partner in the Upton-Kelley Co. He has been an active executive of Ozark Chemical since its formation.

Chemical Company of El Paso, which undertook experimental production of anhydrous sodium sulfate in Dona Ana County, New Mexico. It was later succeeded by the Great Southern Sulphur Company of New Orleans, but there is no record of any active production.<sup>4</sup> During the early twenties the Midwest Dye & Chemical Company produced salt cake and Glauber's salt at its plant near the Garfield smelter on the shore of Great Salt Lake, and in 1920, Western Chemicals, Inc., Tonopah, Nevada, purchased a deposit near San Pedro and erected a \$150,000 plant to purify sodium sulfate and Glauber's salt and to prepare the sulfide and hyposulfite.<sup>5</sup> All this was in addition to its natural soda plant in Nevada which was reportedly turning out 20 tons of potash alum and flowers of sulfur a day.<sup>6</sup> The Iowa Soda Products Company,\* chemical jobbers of Council Bluffs, established a successful natural salt cake business at Rawlins, Wyoming,<sup>7</sup> while the American Sodium Company, working a deposit near Lyon City, Nevada, was that state's leading producer of salt cake. Historic natural deposits at Camp Verde, Arizona, described by O. P. Jenkins in 1923<sup>8</sup> and thought to have been once mined by cliff dwellers, were worked by the Sodium Products Corp.† A production of 90 to 135 tons of 95 per cent salt cake per day was achieved.<sup>9</sup> A sharp deviation from the usual pattern was the Bay Chemical Company, associated with the Myles Salt Company, Ltd.,‡ which operated an original process of its own development<sup>10</sup> at Weeks, Louisiana.

As conditions stabilized in Europe and demand for salt cake in this country grew, imports increased. In May 1929, the Myles Salt Company and the Sodium Products Corporation applied for an antidumping order, declaring that shipments from abroad now filled two-thirds of the domestic demand, forcing several domestic producers to shut down.<sup>11</sup> It was further charged that by importing large quantities and eliminating jobbers' commissions a single American agent—A. Klipstein & Company, representing the Sulfat-Vereinigung—was able to circumvent the antidumping law. At a hearing before the Bureau of Customs the paper-makers pointed out that salt cake is an essential raw material and that domestic producers could not supply their needs. When the tariff was again up for reconsideration, Robert H. Polack, representing the Myles Salt Company, urged a duty of \$5.00 a ton which again was vigorously protested by the kraft paper industry.<sup>12</sup>

Another important sodium salt, the nitrite, also became involved in tariff disputes when it served as a test case to determine whether cost

\* Sales agents for Michigan Alkali and Southern Acid & Sulphur, headed by Don F. Harrison; mgr. of the salt cake plant, Harve Pettigrew.

† R. W. Coad, pres. and gen. mgr.; James Allen, supt.; John Quinn, asst. supt.

‡ Officers of both companies were E. V. Benjamin, pres.; F. W. Mente and Edward B. Benjamin, vice-pres.; Robert H. Polack, secy.-treas.

figures collected during tariff investigations should be made public.\* While its production by the American Nitrogen Products Company was discontinued on the West Coast, the small-scale operation at Syracuse, taken over from Semet-Solvay by Solvay Process, was expanded and developed commercially,<sup>13</sup> and a new use opened up with its use for meat curing was approved by the Department of Agriculture.<sup>14</sup> This authorization followed a test in which several million pounds of meat were cured by sodium nitrite and it was shown that flavor and quality improved with a very marked reduction in curing time.<sup>15</sup>

During the twenties sodium and potassium chlorates had a turbulent career ending in a humiliating climax. Both chemicals were produced by several manufacturers during the war. When demand shrank to peacetime uses, chiefly in matchheads and pyrotechnics and to a limited extent as oxidizing agents, European manufacturers, especially the Germans who had war-excess stocks, began cutting prices to recapture the American market. Makers of the potassium salt were particularly hard hit as they depended upon imported potassium chloride for their raw material.

The duty of 1½ cents was inadequate protection,<sup>16</sup> and by 1923 the sole American producer was the Ohio Salt Company at Wadsworth. The next year only the North American Chemical Company of Bay City, Michigan, was producing.<sup>17</sup> The facts of this ruinous competition were well known, yet the largest domestic consumer, the Diamond Match Company, no doubt to forestall increased duties, asked the Tariff Commission actually to reduce the rate. Counter applications were filed in the spring of 1923 by H. W. Kellogg for the National Electrolytic Company of Niagara Falls and M. L. Davies for the North American Chemical Company.<sup>18</sup>

The Tariff Commission ordered an investigation of comparative costs which was completed in August 1923 and a report submitted to the President on April 2, 1925.<sup>19</sup> The tariff was advanced by 2½ cents. This was still inadequate, though the North American Chemical Company, whose general manager was C. F. Hutchings, and the Oldbury Electro-Chemical Company struggled on.† Both were operating an electrolytic process. The North American Company, with a cell capacity greater than the sodium chlorate market, used this excess capacity to electrolyze imported potassium chloride to potassium chlorate, but en-

\* See Chap. 2.

† The National Electrolytic Co., the North American Chemical, and the Oldbury Electro-Chemical all began producing chlorates in the late 1890's. National and North American were the largest wartime producers of the potassium salt. Oldbury has made sodium chlorate uninterruptedly since 1902 and resumed production of potassium chlorate in 1933. National went out of business about 1922 and North American in 1926. (E. L. Whitford, to author, May 7, 1946.)

countered economic and technical difficulties. The German potassium chloride contained a rather high percentage of sodium chloride which complicated the electrolysis. Oldbury, on the other hand, produced sodium chlorate from native salt by electrolysis and then potassium chlorate by double decomposition of sodium chlorate and potassium chloride in which the salt impurity in the crude potassium chloride was not a handicap.<sup>20</sup> Despite this intelligent, chemical subterfuge, even Oldbury gave up the battle, and by 1929 American consumption of potassium chlorate was supplied entirely by imported material.<sup>21</sup> Oldbury continued, however, to produce sodium chlorate which had a new industrial importance due to its use as a weed killer. Consumption increased from less than 500 tons in 1924 to 5,000 tons in 1929.<sup>22</sup>

Other sodium salts were profiting by new uses. Sodium aluminate for treatment of boiler feed water, both directly and in lime-soda softening plants, rapidly found favor. Being an alkaline coagulant and possessing softening qualities of its own, it speeded the lime-soda reaction and at the same time cut down the amount of lime and soda ash required. Additionally it inhibited foaming and was particularly valuable in removing magnesia and silica.<sup>23</sup> Sodium hydrosulfite, whose largest use had been as a reducing agent and for application of vat and sulfur dyes, began to be used in the preparation of dyes, Salvarsan, arsphenamine, and other organic compounds, as well as a bleaching agent for straw, sugar, molasses, and soap.<sup>24</sup>

Methods of preparing sodium sulfide also came in for thoroughgoing investigation. A number of new furnaces were developed, but none supplanted the old reverberatory type. Of these new furnaces, an electric one perfected at the Shawinigan plant of the Canadian Electro Products Company, Ltd., by Horace Freeman,<sup>25</sup> did come into commercial use in Canada. Its product, said to be 90 per cent  $\text{Na}_2\text{S}$ , was particularly adapted for the precise requirements of textile dyeing and leather manufacture. Nevertheless it could not compete with the cheaper, 62 per cent material offered by both domestic and foreign makers. Later by-product hydrogen sulfide from petroleum refineries, absorbed in alkali, began to compete with the old process of reducing the sulfate with coal.

Among the alumina derivatives the technical progress and new applications had less effect during these years than they did on the sodium compounds. In fact the significant happenings concerned the raw material, bauxite. Material imported from British and Dutch Guiana eliminated imports from Europe \* and even assumed control over American production, especially for aluminum and chemical processes.<sup>26</sup>

The ascendancy of South American bauxite did not, however, quench

\* "I have never heard of European bauxite being used for alum except possibly indirectly from hydrate produced by Penn Salt." (F. C. Frary, to author, May 20, 1946.)

interest in American deposits. In 1923, the year following the first shipments from Surinam, Henry Ford bought six bauxite mines in southern Georgia, at a cost estimated between \$500,000 and \$1,000,000.<sup>27</sup> He was an active bidder for the Muscle Shoals hydroelectric plants and anticipated entering into aluminum production. That year domestic production reached half a million tons,\* a quantity only exceeded during the war years of 1917-18 and not again passed until World War II.<sup>28</sup> Biggest producer was the American Bauxite Company, subsidiary of the Aluminum Company, whose plant at Bauxite, Arkansas, handled some 1,500 tons daily. New deposits were opened in central Georgia and east-central Alabama.<sup>29</sup>

After this booming year American production declined steadily. Eastern mines in Georgia and Alabama, which were petering out, delivered a diminishing share of the national total, which was increasingly supplied from Arkansas.<sup>30</sup> Two events accelerated the fall of domestic output. The Aluminum Company, largest American consumer, had acquired mines in British Guiana and Surinam and began drawing more heavily upon them. In 1923 Arkansas placed a tax of 25 cents a ton on all bauxite mined.† Although this was modified to 2½ per cent of the gross value of the mineral at the point of severance (amounting to about 5 cents a ton), nevertheless the American Bauxite Company sharply curtailed production at this time.<sup>31</sup>

Before the close of the decade American mining picked up again and the use of bauxite by the chemical industry increased by 21,000 tons in 1928 over 1927, adding 3,000 more tons in 1929.‡ Much of this chemical growth was accounted for by the use of aluminum chloride in petroleum refining.

In 1915, Almer McDuffie McAfee,§ Texas-born and educated, a "first settler" of the great Sabine petroleum center, demonstrated for the first time on a large scale that high-boiling petroleum oils could be catalytically cracked into gasoline in a 1,000-barrel, cheese-box type stirring still operated at 500-600° F. and at atmospheric pressure, employing aluminum chloride as the catalyst. At the same time, he demonstrated that at

\* For U. S. production of bauxite and consumption in various industries, see Appendix XXIX; for imports, Appendix V; for exports, Appendix VI.

† Act No. 118 of the Ark. Gen. Assembly, Feb. 14, 1923, effective Apr. 1, 1923. Mines producing in the state at the time were owned by the American Bauxite Co., Globe Bauxite Co., Southern Bauxite Co., Superior Bauxite Co., and Republic Mining & Mfg. Co., which last suspended operations that year.

‡ See Appendix XXIX.

§ After getting his A.B. at U. Texas, 1908, and Ph.D., Columbia, 1911, McAfee was chem. for the Texas Co. until 1913, when he joined the research staff of the Gulf Refining Co., Port Arthur. Holder of numerous U. S. patents on the manufacture and use of aluminum chloride, McAfee is prominent in civic affairs. He was born near Corsicana, Sept. 24, 1886.

lower temperatures aluminum chloride brings about profound internal changes in petroleum, a rearrangement of the hydrocarbons and the removal of unstable bodies. Thus aluminum chloride is capable of playing a dual role—one of catalytically cracking and one of rearranging and refining petroleum hydrocarbons. Both actions could be made to take place simultaneously or separately, depending on the temperature employed.

Years before von Baeuer had said that the uses of aluminum chloride sound like a fairy tale. In 1915 McAfee realized he was merely embellishing the fairy tale unless a method could be developed for the manufacture of cheap aluminum chloride in thousands of tons—not pounds. It took three years and approximately \$1,000,000 of the Gulf Oil Corporation's money to learn how to do this.\*

There was no precedent to follow. It was easy to make aluminum chloride from metallic aluminum, but that was much too expensive. McAfee paid \$1.50 a pound for the aluminum chloride used in experimental work. He realized that if there was to be any commercial use in the petroleum industry, the aluminum chloride would have to come from the direct chlorination of bauxite in the presence of carbon. But that had never been accomplished except in the laboratory for the reason that in order to chlorinate bauxite, temperatures ranging from 1,600-1,800° F. are required. Chlorine is a lively reagent at atmospheric temperature; at 1,600° F. no metal can withstand its action, and bricks are consumed in the presence of carbon.

The story of three years of trial and error (1915-18) has been told by McAfee,† but from 1918 until the time he delivered his paper before the American Institute of Chemical Engineers in 1929, giving the details of the method of manufacture, Gulf at its Port Arthur, Texas, refinery had made approximately 146,000,000 pounds of aluminum chloride by the direct chlorination of bauxite in the presence of carbon. The particular significance of the 1929 paper was the announcement that it would be the policy of the Gulf organization to make aluminum chloride available for all uses as freely as possible in excess of Gulf's requirements, at a price of 5 cents per pound in carload lots. No one had ever before offered aluminum chloride in such quantities and at such a price, and the chemical engineers in Philadelphia who listened to this paper were quick to realize that at last some of the fairy-tale uses of aluminum chloride could now come true.

In 1918 Gulf started building at Port Arthur additional 1,000-barrel

\* I am indebted to Dr. McAfee for detailed memorandum covering these discoveries and their development, dated May 17, 1946. (W. H.)

† *Trans. Am. Inst. Chem. Engrs.* 8, 177 (1915), 22, 209 (1929); *Ind. Eng. Chem.* 21, 670 (1929).



stills similar to the one in which the first demonstration was made in 1915. During the 1920's the company had built at Port Arthur twenty-seven 1,000-barrel stills and three at Forth Worth for the purpose of cracking high-boiling oils with aluminum chloride into gasoline, which was marketed as Gulf No-Nox gasoline. In those days the word "octane" had not been invented, and neither had tetraethyl lead. Gasoline made by aluminum chloride was water-white, sweet-smelling, and had superior anti-knock properties. Gulf was thus the first by many years to produce and sell gasoline made by catalytic cracking. During the 1920's, however, there was steady improvement in the methods of thermally cracking high-boiling oils into gasoline, and a constant expansion of this process in the whole petroleum industry. Costs were steadily lowered as new techniques were developed and volume increased. By 1929 thermally cracked gasoline had been so reduced in cost that aluminum chloride gasoline could not compete, particularly in view of the fact that tetraethyl lead had come into the picture.

The other use to which Gulf was putting aluminum chloride in 1929 was in the manufacture of premium-grade lubricating oils. By 1927 the automobile engine had been so improved in respect to high compression and high speed that superior lubricating oils were required, and Gulf started making Gulfpride oils by the Alchlor process. By 1929, when aluminum chloride was run out of the gasoline business, the quantity required for Gulfpride oils was comparatively small, hence Gulf had excess aluminum chloride on hand, and consequently offered it for sale.

During these years capital work was being done on the more economical production of aluminum chloride by Bernard H. Jacobson\* at the South Charleston plant of E. C. Klipstein & Sons and at the Niagara Falls plant of Savell, Sayre & Company under direction of Walter L. Savell.† So successful were these quite independent efforts that long before the Gulf Oil Corporation offered aluminum chloride in the open market, pure material was available at reasonable prices for use as a catalyst in the production of the vat dye intermediate, anthraquinone, by condensation of phthalic anhydride and benzene, and for organic chlorination operations, where it acts as a chlorine carrier.<sup>32</sup> The pre-war price of \$7.50 per pound had come down to 22 cents in 1922 and was further reduced to 12 cents in 1928.<sup>33</sup>

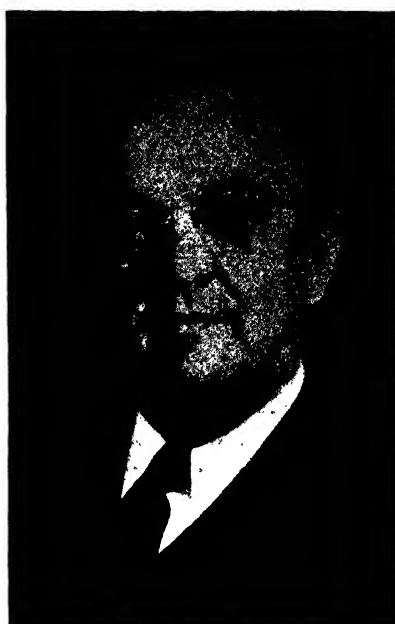
The aluminum chloride which came on the market in 1929 from the McAfee-accomplished direct chlorination of bauxite in the presence

\* See Vol. III, p. 274.

† A Californian by birth (Feb. 13, 1890), Savell was educated at U. Ga. and Queen's U. (Toronto). He was chem. for the Delore Smelting & Refining Co. and Harshaw Chemical before forming Savell, Sayre (1915-25), and since 1928 consultant for Mathieson Alkali. He is coauthor of *Standard Methods of Analysis*, and now (1946) dir. chem. research, Remington-Rand, Inc.



E. W. MENTE



MAHLON J. RENTSCHLER



EDWARD V. BENJAMIN

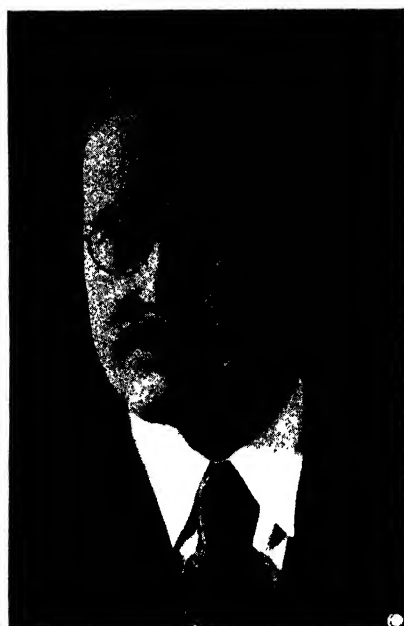


*Chemical & Metallurgical Engineering*

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A. M. McAFEE



WALTER L. SAVELL



COLIN G. FINK

of carbon,\* was not the 99 per cent anhydrous chloride produced by the older process. It contained traces of iron and other impurities, but at 5 cents it was feasible for large-scale operations in the liquid-phase cracking of petroleum and in the dye and other industries.<sup>84</sup> Bauxite itself was suggested for direct use in petroleum cracking.<sup>85</sup> A good refining agent for kerosene, bauxite proved a capital colloidal absorbent for organic sulfur derivatives, for use in sulfur-contaminated crudes. Shortly afterwards a new process † for dehydrating bauxite appeared, producing a porous cake impervious to water, which stored and handled better than dried or calcined forms.

Aluminum chloride was not the only aluminum salt subjected to intensive researches. The tempting possibility of employing cheap, aluminous clays in place of bauxite was pursued eagerly, albeit unsuccessfully. Growth of the paper industry inspired much work to eliminate iron contamination of aluminum sulfate—iron-free alum sold at twice the price of the commercial grade, but this could only be achieved at the time by starting with a virtually iron-free bauxite or clay.<sup>86</sup>

Consumption of this most important aluminum salt, which then ran about 12,000 tons yearly,<sup>37</sup> was supplied by 22 different plants, the principal producers being General Chemical, Kalbfleisch (American Cyanamid), Harrison (du Pont), Monsanto, Merrimac, and Pennsylvania Salt.<sup>38</sup> In 1926 General Chemical built a new ammonia and potash alum plant at its Delaware works.<sup>39</sup> In 1928 E. I. du Pont de Nemours & Company purchased the alum plant of the North Hudson Chemical Company at Albany, New York.<sup>40</sup> This company had grown after the war out of the chemical firm of Lesser & MacGruer, both Albany men and Williams graduates, Rudolph W. Lesser having been previously associated with Metz and National Aniline.‡ The small plant, which was under the superintendence of George Walker,§ was later dismantled and its production transferred to du Pont's Harrison works at Philadelphia.<sup>41</sup>

Initial American production of the so-called aluminous cement came in 1924 at the Northampton, Pennsylvania, plant of the Atlas Luminite Cement Company.<sup>42</sup> This attracted attention for its quick hardening

\* U. S. Pat. 1,867,672 (1932), filed Sept. 30, 1927, ass. to Gulf Refining Co.

† R. W. Hyde, U. S. Pat. 1,655,608 (1928), ass. to Dwight & Lloyd Sintering Co.

‡ Lesser, treas., had been born in Albany in 1886 and had entered the dye business as a salesman for I.G. John A. MacGruer, pres., was born in Ogdensburg, N. Y., in 1890, had served in the field artillery during the war, and in 1923 was appointed a receiver of the Albany Chemical Co.

§ An experienced plant operator, Walker learned his chem. eng. at Dartmouth, Columbia, and Mass. Inst. Tech. His practical training was with the New England Mfg. Co. (1915-16), Dorr (1920-22), and Grasselli (1922-23), and he became North Hudson's works mgr. in 1924, and Soya Div. mgr. at Glidden in 1935. He was Lt. in the Explosives Div., Ordn. Dept., 1917-18.

and its chemical and heat-resistant properties, and a bauxite shortage was enthusiastically forecast. This optimistic fear proved groundless. While the calcium aluminate cements are at a premium for chemical and refractory work, their early hardening has been offset by fine grinding and greater lime content in Portland cement. Indeed, in general, the refractory uses of bauxite declined during this period, though a large California deposit of andalusite, a natural anhydrous aluminum silicate, was worked at the rate of 3,500 tons a year by the Champion Porcelain Company and shipped to Detroit for manufacture into its affiliated company's spark plugs.<sup>43</sup>

The war-born barium chemical industry had an exciting youth.\* Demand for all its products expanded. Competition from imported raw material and finished products alike was severe, and American companies that mined barytes or made barium compounds all encountered rough going. Shutdowns, even dissolutions, were numerous, and the most important barium chemical manufacturing unit underwent complete reorganization. By the end of the twenties, however, the new industry had established itself firmly in our chemical economy.

The close of the war loosed a flood of imports. German producers enjoyed definite advantages in that American deposits of barytes † occur frequently in scattered blocks, while in Germany the veins of ore are thicker and richer. Mines in Missouri produced at this time half of the domestic output; the balance came from Georgia and Tennessee. The critical year was 1926, when the use of barium compounds, thanks chiefly to the popularity of lithopone (a mixture of chemically equivalent quantities of barium sulfate and zinc sulfide) as a paint pigment, grew markedly.<sup>44</sup>

The turn came after a dismal and discouraging period. In 1922 the plant of the American Barium Company at San Francisco burned with a loss of \$200,000.<sup>45</sup> This left the West Coast without a barium chemical operation until 1924, when Barium Products, Ltd., started at Modesto, California, which was later taken over by United Chemicals, Inc. In 1923 the affairs of the Rollin Chemical Company of Charleston, West Virginia, had to be placed in the hands of a creditors' committee headed

\* Production figures of several barium salts are in Appendix XXX; imports, Appendix V; exports, Appendix VI.

† Barytes, known also as barite or heavy spar, is natural barium sulfate ( $\text{BaSO}_4$ ) containing from 5-10% impurities, used largely as an extender for paint pigments and a filler for paper and rubber. Precipitated barium sulfate, prepared by precipitating a soluble barium salt with sodium sulfate or obtained as a by-product in the manufacture of hydrogen peroxide from barium dioxide and sulfuric acid, is known as blanc fixe. It has many of the same uses as the crude salt, but is whiter and finer and finds employment in the manufacture of pigments by precipitating on it organic lakes or titanium, the last producing the trade-marked Titanox. For consumption of barytes and producers of barium products therefrom, see Appendix XXXI.

by Horace G. Carrell.<sup>46</sup> Efforts to effect a settlement of claims, which totaled \$1,211,707, failing, the plant, mines, and business were purchased by the recently organized Barium Reduction Corporation. The business was entirely revamped.<sup>47</sup> The pigments business was cultivated not only in lithopone, but in the sale of blanc fixe (barium sulfate) to the Titanium Pigment Company for the production of Titanox, and a new demand was supplied when the Tubize Artificial Silk Company required large quantities of sodium sulfhydrate for its operations at Hopewell, Virginia. Sales, which had previously been handled by the Clinchfield Products Corporation, were placed in the hands of John G. Harrison by the new president, James Johnston Riley.\*

A newcomer was the Alton Barium Products Company, organized in 1926 by a local financier, August Luer, who placed Merrill E. Turner, secretary of the Alton Banking & Trust Company, in active charge of this enterprise. Production manager was Irvin Walter Brandel,† who had formerly been in charge of the Alton plant of the Consolidated Chemical Products Company of Chicago. With the Chicago Copper & Chemical Company plant at Blue Island, Illinois, and the J. H. R. Products Company at Willoughby, Ohio, which Mahlon J. Rentschler ‡ had founded in 1917, the center of the barium chemical industry began to gravitate in the Middle West so as to draw advantageously upon barytes from Missouri.

Lithopone was fast making barium sulfate the most important item of this group.<sup>48</sup> In 1924 the Arkansas Bauxite Products Company, of which George W. Goodman was secretary-treasurer and active head, announced that it would manufacture this chemical in a new \$40,000 plant at Little Rock.<sup>49</sup> A new process for the extraction of practically pure barium sulfate from barytes was perfected by Edward Doty, president of R. K. Miller Minerals Corporation of Cartersville, Georgia.<sup>50</sup> It was based upon the ability of molten sodium chloride to dissolve and hold barium sulfate in solution to the exclusion of other minerals in the

\* Irish-born, Canadian-raised Riley was one of the most widely popular chemical leaders of his day. Before the war he had been vice-pres. of Northern Explosives Co., 1905-11, and of Curtis & Harvey, Ltd. (Can.), 1911-17. A retired Lt. Col. of Canadian Cavalry, he maintained his interest in riding and showing horses and amateur athletics. When Barium Reduction was sold in 1938, Riley retired.

† At U. Wis., Brandel switched from pharm. (Ph.G., 1899) to chem. eng. (B.S., 1901), getting his Ph.D. in 1906. From 1910-14 he was a consulting engr. in Seattle; 1914-17, with the Midland Chemical Co.; 1917-25, with Consolidated Chemical Products. He served on the U.S.P. Revision Comm. and the Food & Drug Administration as expert collaborator; and originated the quinhydrone theory of plant pigmentation.

‡ Rentschler had been 5 yrs. with the Oakland Chemical Co., pioneer makers of barium peroxide from which hydrogen peroxide was prepared for the retail trade. He was graduated from Penn. State Coll. (B.S., 1904; M.S., 1908) with 2 yrs.' postgraduate work at Göttingen, and besides teaching at his Alma Mater, was asst. to Dr. Chas. B. Dudley in the Altoona Labs., Penn. R. R. He was born Apr. 19, 1882, at Centreport, Pa.

ore, the sulfate being subsequently dissolved out in water in a finer, lighter form than that produced by any other process.

Barium carbonate also branched out into new fields. Long the raw material of the dioxide and other barium compounds, and as a fusing agent in porcelain enamels, rat poison, and a factor in the manufacture of case-hardening compounds and optical glass, this salt became an additive to clay to prevent the formation of scum in the stiff-mud brick process.<sup>51</sup> Barium pellets also began to be used, as the metal itself or in alloys with magnesium and aluminum, by the radio industry to clean up the last traces of gas in vacuum tubes.<sup>52</sup>

From 1923-26 imports of barium carbonate increased markedly while the price of imported material dropped lower and lower.<sup>53</sup> By the middle of 1924, when the Bertha Mineral Company at Sweetwater, Tennessee, shut down, only two American producers, Barium Reduction and Chicago Copper & Chemical, remained active. Early in 1926, however, the three principal German producers, Rhenania Kunheim Verein, Harkotsche Bergwerke, and Niederheim formed a cartel and thereafter prices of imported material began to rise.<sup>54</sup> Next year, Alton Barium Products Company reopened after several years' shutdown.<sup>55</sup>

On February 20, 1925, the Tariff Commission was requested to increase the duty on barium sulfate. After collecting cost data from domestic and foreign makers, the Commission recommended an increase which was granted by Presidential proclamation, March 26, 1928, raising the duty from 1 cent to 1½ cents a pound.<sup>56</sup>

The duty on barium peroxide had previously been raised. Of the two domestic producers, the Oakland Chemical Company, New York, made barium peroxide for its own use, while J. H. R. Products Company sold to other peroxide manufacturers. The latter requested an increase in duty, November 28, 1922,<sup>57</sup> and a month later John Bené & Sons, importers of New York City, filed a counter request for a decrease. Investigations were conducted here and abroad by the Commission, May to July 1923, and a public hearing was held November 9. The devaluation of the German monetary system when the Rentenmark was introduced, radically changed German production costs and further investigation was made. The duty on barium dioxide was increased from 4 to 6 cents a pound, May 19, 1924, and two years later this raise was sustained by the General Board of Appraisers.<sup>58</sup>

When the new tariff was up for consideration in 1929, the old conflict of interests over what is a chemical raw material cropped up and the Oakland Chemical Company filed a brief opposing any increase in duty on barium oxide.<sup>59</sup> The need to import an intermediate product under as low a duty as possible was pleaded in order to carry on further manufacture to the dioxide, which was already protected. On the other side,

Barium Reduction, joined by Barium Products, J. H. R. Products, and Chicago Copper & Chemical, asked for a higher duty.<sup>60</sup>

Similar opposing views arising out of different chemical applications appeared in the Tariff Commission's study of the duties on magnesite. The crude mineral, which is the carbonate, seldom gets to the market. Heat easily drives off carbon dioxide, reducing the weight by half, so that the calcined forms of commerce are, chemically speaking, oxides, calcined or dead-burned.<sup>61</sup> The former reacts with magnesium oxychloride to form so-called Sorrel cement; the latter is used in refractories and as starting point in the manufacture of other magnesium compounds.

The familiar story is repeated. Consumption of magnesium chemicals and of magnesite refractories both grew, but imports swamped the market and American production, which had flourished during the war, withered sadly. Imports of magnesite, both crude and calcined, came chiefly from Austria, though shipped through the ports of Italy, Germany, and the Netherlands; magnesium chemicals, especially Epsom salt and magnesium carbonate, came from Germany. Austrian miners made the well-known opening lead by applying for a decrease in the tariff on April 30, 1923, and in August the Tariff Commission instituted the customary cost investigation.<sup>62</sup> Other pertinent data were gathered, and hearings held December 5, covering the crude, the caustic calcined, and the dead-burned grades. Figures and testimony alike indicated that an increase, not a decrease, in the tariff was equitable, and the foreign applicants requested an indefinite postponement of action. Two important American producers, the Sierra Magnesite Company and C. Maltby, petitioned for a raise in the duty, and the Commission voted to continue its investigation, holding another public hearing, June 21, 1926. Its final report recommended an increase in duties which was effected by Presidential proclamation, November 10, 1927. The rate on crude was advanced from 5/16 cents a pound to 15/32 cents and on caustic calcined from 5/8 cents to 15/16 cents.<sup>63</sup>

At this time, six mining and calcining plants, among which two in California were conspicuously the greatest producers, supplied almost all the caustic calcined magnesite in this country. The year after the tariff rate was raised, the principal European producers banded together in a cartel.<sup>64</sup>

From the chemical point of view, the memorable event of these years was the exploitation of magnesium chloride as a source material for magnesium compounds. As early as 1912 the Dow Chemical Company had begun its conscientious development of the products procurable from Michigan brine, and one of its early recoveries was magnesium chloride, from which the production of magnesium sulfate was an easy step. Production of both products increased greatly during the war and



continued afterwards. In 1927 the Marine Chemicals Company, Ltd., began a purely experimental recovery of magnesium hydroxide from sea water at its plant on Point San Bruno near South San Francisco. Under R. E. Clarke the policy was adopted of cautious, pay-as-you-go expansion, but by 1929 this operation had proved its commercial worth.<sup>65</sup> In this interesting project Paul D. V. Manning,\* who as consulting chemical engineer at San Francisco played an important role in a number of West Coast developments, served as vice-president of the corporation and technical advisor.

Dow, which in 1929 announced a commercial production of Epsom salt from magnesium hydroxide by a new process,<sup>66</sup> persevered manfully in the production of magnesium. Prior to World War I this metal was but a short step outside the laboratory, but tracer bullets and flares created a need that was met in this country by several companies.† Of these there were the two postwar survivors, Dow and the American Magnesium Corporation, which had been acquired by the Aluminum Company. In February 1920, a devastating fire, the second, reduced to scrap iron the little Dow plant of 16 electrolytic cells producing 800 pounds of magnesium daily, and since no market for the metal existed and the acute postwar depression was on, production was not resumed until 1922. In the interim the American Magnesium Corporation remained the sole American producer.<sup>67</sup>

Dr. Herbert H. Dow, vividly described by *Fortune* as "an old-fashioned free-enterpriser, creative, independent, dogged in purpose,"<sup>68</sup> determined not only again to produce magnesium, but to win for this light metal the place which his vision foresaw that it must come to occupy as a structure material and in alloys. Five nerve-breaking years of hard work and discouragement followed.‡ A long, costly research improved the process. A new series of structural alloys, christened Dowmetal, were developed. Casting, forging, and other fabricating techniques were investigated and perfected.<sup>69</sup> Enthusiastic but disheartening efforts were made to find markets for these products. The Ger-

\* Research dir. of the International Mining & Chemical Corp., Chicago, since 1941, Manning has been prominently identified with such West Coast enterprises as the Inyo Chemical Co. (1925-26), the Western Condensing Co. (1936-41), and the Golden State Co. (1939-41). He was born in Omaha, May 4, 1893, and educated at Stanford, A.B., 1916; Calif. Inst. Tech., M.S., 1917; Columbia, Ph.D., 1927. Before returning to the West, he was research engr. with the Chile Exploration Co., the International Coal Products Co., and the Bregreat Corp. in N. Y. During World War I he did research for the Nitrate Div., and was for years asst. ed., *Chem. Met. Eng.*

† See Vol. II, p. 234.

‡ The story was told in great detail by Dr. Willard H. Dow in his testimony before the Senate Special Committee Investigating the National Defense Program, Mar. 6, 1944, which was reprinted by Dow Chemical as a pamphlet, *Dow and Magnesium*. (See also *Fortune* Apr. 1928, Dec. 1942; and Haynes, *Chemical Front*, p. 226.)

man I.G., then the world's largest producer, had developed a series of magnesium alloys known as Elektrons, and viciously opposed establishment of magnesium production in this country, even setting up the Elektron Metals Corporation here to exploit its products. In 1924 this German company was suspended,<sup>70</sup> and in 1927 the American Magnesium Corporation in which the Aluminum Company had centered its alloy-making activities, gave up production of magnesium to confine its activities to casting and fabricating the metal and its alloys.<sup>71</sup> By default, thanks to Dr. Dow's stubborn faith, the Dow Chemical Company had become the only American producer and with the sale of ingots to its late rival, the business began to assume tangible size. In 1929, for the first time, magnesium showed Dow a return above operating and experimental expenses. Dow output of the metal had grown from 22,664 pounds in 1922 to 840,344 in 1929. The price, which during the war hit \$5 a pound, dropped from \$1.60 in 1922 to 56 cents in 1929.<sup>72</sup>

Mastery of a chromium-plating technique, creating a new market for chromic acid, was the signal development among this group of chemicals during the 1920's. Chrome electroplating had been accomplished as far back as 1854 by Bunsen, but in spite of its many obvious advantages the process remained experimental until the middle twenties, when a sharp burst of activity resulted in several patents taken out by Union Carbide and Carbon and its subsidiary, the Electro Metallurgical Company, the Vacuum Can Company, the Metal & Thermit Corporation, the Chemical Treatment Company, and others.<sup>73</sup> One of the most important was issued to Dr. Colin G. Fink,\* and assigned to the Chemical Treatment Company.<sup>74</sup>

A threatening snarl of patent interferences, which would have delayed commercial application of this new art, was largely cleared up by consolidations which gathered together these rights. In 1926 the Chromium Corporation of America was formed to take over the patents of the Chemical Treatment Company and the Chromium Products Corporation, subsidiary of the Metal & Thermit Corporation. John T. Pratt, president of Chemical Treatment, began as chairman and Dr. F. H. Hirschland, as president of the new corporation. Operations were in charge of vice-presidents Louis C. Owens, Jr., and Richard Loengard, at the Chromium Products plant in Jersey City and the Chemical Treat-

\* Discoverer of ductile tungsten, Dr. Fink has headed the Electrochem. Div. at Columbia U., his Alma Mater (A.B., 1903), since 1922. He received his Ph.D. from Leipzig in 1907, when he joined the research staff of General Electric, leaving to direct research at the Chile Exploration Co. (1917-21). The Acheson and Perkin medals have been tendered to him and in 1940, the Modern Pioneer award. He has been a member of the Nat. Res. Council since its reorganization in 1918, American delegate to the Internat. Cong. Chem. in Rome, and during World War II was chmn., Tungsten Comm., Munitions Bd. Dr. Fink was born in N. J., Dec. 31, 1881.

ment plants in New York and Waterbury, Connecticut.<sup>75</sup> Next year, the General Chromium Corporation strengthened its position by acquiring the patents of the Vacuum Can Company, the Electro Metallurgical Company, and the Union Carbide and Carbon Research Laboratories,\* and pushing the chrome-plating business of the group.<sup>76</sup>

The National Chromium Corporation, which was incorporated in New York in 1927, developed a process for chrome-plating aluminum in which a preliminary coat of nickel was employed.<sup>77</sup>

Shortly after the issuance of the Fink patent, an interference was declared by the Patent Office at the request of Marvin J. Udy, who was employed by the Electro Metallurgical Company and whose patent application had been assigned to the General Chromium Corporation of Detroit by the Electro Metallurgical Company. As the issued Fink patent and the Udy application, which was in interference, covered the same process and as they were controlled by different owners, any company or individual desiring to do chromium plating was faced with the difficulty of trying to determine who actually owned the invention under which they desired to operate. This situation most definitely interfered with the free development of commercial chromium plating for which a great demand had developed at that time. To make it possible to carry on chromium plating assured of freedom from litigation by obtaining a license under the dominating patents, both Chromium Corporation of America and General Chromium Corporation agreed that it would be to the advantage of American industry to have these patents placed in one company so that one license might be granted which would carry with it assurance that the licensee was fully protected. This led to the formation of United Chromium, Inc., in August 1927.<sup>78</sup>

The Oldsmobile displayed at the 1925 Automobile Show caught the public attention with its chromium-plated radiator.<sup>79</sup> The eye-appeal of this novelty was quickly substantiated by the good service rendered and this coating was promptly adopted and extended to other bright metal parts by other motor-car makers. Chrome-plated plumbing fixtures followed almost immediately and the popularity of the finish spread with astonishing rapidity. Chromic acid (chromium trioxide,  $\text{CrO}_3$ ), previously a rather insignificant medicinal chemical prepared by Merck and Mallinckrodt for use as a caustic, astringent, and germicide, became suddenly an industrial product. The makers of chrome chemicals—Mutual Chemical and Natural Products Refining, specialists in this field, and Grasselli—all entered into its manufacture.

This flattering commercial attention naturally instigated researches

\* Dir. were A. E. Baldwin and Horace Maynard, General Chromium; F. J. Fisher, General Motors; B. O. Smith and Roy Gleason, Vacuum Can; B. O'Shea and F. M. Becket, Union Carbide.

in the manufacture of this acid, and it soon appeared in quantity of a purity actually higher than U.S.P. requirements. The plating process was also studied and means sought to eliminate the preliminary underplating with another metal.<sup>80</sup> The Bureau of Mines, cooperating with the University of Nevada, worked out a cheaper process for the production of chromium oxide ( $\text{Cr}_2\text{O}_3$ ), evolving a laboratory-scale production of a chemically pure product adaptable for commercial application.<sup>81</sup> Another repercussion was a request for increased duty on chromic acid in the 1929 Tariff. When the 1922 rates had been written, this chemical, generally imported, was of small interest, but it had now become a matter of concern to several American manufacturers who were meeting severe price competition from the imported product.<sup>82</sup>

One other notable change occurred in this group. In 1923 the world source of crude chromite for chemical manipulation changed definitely from New Caledonia to Rhodesia, while at the same time India worked up to second place.<sup>83</sup> By 1925 American chemical manufacturers had completed the gradual switch to the high-grade, soft-type ore from Rhodesia,<sup>84</sup> and by the end of the decade it was observed that Rhodesian and other South African chromite was tending towards marketing by a single syndicate.<sup>85</sup>

Sodium silicate continued its wartime growth so that the eight firms which in 1914 turned out \$1,649,000 worth became 23 firms in 1929 with production valued at \$7,179,000.<sup>86</sup> Its application as an adhesive in boxboard and cartons grew with the increase in this type of container. In 1918 the first concrete roads were being cured with sodium silicate in Dallas County, Texas,<sup>87</sup> and some ten years later the use of silicate solutions in stereochromic painting, a term coined by von Fuchs, the first manufacturer of this solution on a commercial scale, was being introduced.<sup>88</sup> The largest American producer of silicates, the Philadelphia Quartz Company, which specialized in these products exclusively, purchased the silicate plant of the Central Commercial Company at Utica, Illinois, in 1928, and at the close of the period was operating seven plants in this country.<sup>89</sup>

Cheap synthetic ammonia affected all ammonia salts and the boom in radio raised the consumption of sal ammoniac in the "B" and "C" dry batteries. In fact, during the fall contract season of 1927, an acute shortage developed, although domestic production had been stepped up and imports had increased from 4 to 14 million pounds since 1921.<sup>90</sup> The small-scale productions of ammonium chloride and bicarbonate, which were taken over from Semet-Solvay by Solvay Process in 1926, were both expanded and developed into sizable commercial operations.<sup>91</sup> An electrolytic process for the manufacture of pure ammonium persulfate,  $(\text{NH}_4)_2\text{S}_2\text{O}_8$ , developed by the North American Chemical

Company of Bay City, Michigan, was bought in 1928 by the Pennsylvania Salt Manufacturing Company and moved bodily to the Wyandotte plant where it was operated by personnel retained from Bay City.<sup>92</sup>

In this far-flung field of inorganic industrial chemicals, a couple of other developments of this period are especially noteworthy. In 1925 the Diamond Alkali Company, which had already diversified by adding silicates, began the production of calcium carbonate at its Painesville, Ohio, plant, a move that led to the establishment of its Pure Calcium Products Division.<sup>93</sup> During the middle twenties the Aluminum Company of America, which for years had been experimenting with the manufacture of artificial cryolite, the natural double fluoride of sodium and aluminum found only on the west coast of Greenland and used as a flux, reached the point where it began regularly to manufacture and use the substitute. The principal raw material in this process was fluor-spar, and during that year the company purchased one large and 15 small fluor-spar properties in the Illinois-Kentucky fields.<sup>94</sup> Although the amount of cryolite consumed as an aluminum flux was said to have averaged some 2,000 tons a year, initially this new development had but little effect upon imports of the mineral which had always been handled by the Pennsylvania Salt Manufacturing Company as exclusive selling agents for the Danish Government. These imports continued to increase due largely to the use of cryolite in opaque glass.<sup>95</sup>

Distinguished from most heavy chemicals in that the raw material was located in the United States but controlled by foreign interests which had ascendancy over world markets, borax and its derivatives, boric acid, had an exceptional record. During the twenties some dramatic chapters were added. Production advanced sensationally from 6,854 tons in 1923 to 119,970 in 1929.<sup>96</sup> The price went down in almost inverse ratio from \$105 to \$50 a ton. From a high-priced specialty borax became an industrial commodity and new markets opened successively continued to absorb the increased output. Makers of blown and pressed glassware, for example, discovered that at the new price, substitution of 10 per cent borax for soda ash gave a better and actually a cheaper product. The textile industry found borax to be an exceedingly advantageous scouring agent, as its solution has an hydrogen-ion concentration approximately that of neutral soap, acting more efficiently as an alkali buffer than the modified sodas. This application spread to the laundry and other cleansing fields.<sup>97</sup>

Behind this demonstration of the modern sales theory which seeks greater profit by selling more goods at lower prices were two significant developments touching the two most important borax companies. After years of expensive experiment, the American Potash & Chemical Corporation, working up the brine in Searles Lake, perfected its process

of separating borax and potash in a plant which was hailed as a "striking example of the cash value of the phase rule."<sup>98</sup> The operation became the largest borax plant in the world, and in 1927 began the production also of technical and U.S.P. grades of boric acid, enlarging the acid plant in 1928.<sup>99</sup>

Late in 1926 deposits of a new type of borax were discovered in Kern County, California, by C. M. Rasor and named after him, rasorite. Differing from ordinary sodium borate, the decahydrate, in containing but four molecules of water, the deposit was snapped up by the Pacific Coast Borax Company.<sup>100</sup> Fifty-three test holes were bored to 600 feet, and a deposit 100 feet thick proved in a field five miles long and more than three miles wide.<sup>101</sup> These workings proved so remarkably economical that the company promptly decided to abandon its historical and romantic mine in Death Valley.<sup>102</sup> A new plant was built thirty miles east of Mojave, a new process worked out,\* and since lower costs put the company in an extremely competitive position with the Searles Lake brine, production started on an unprecedented scale. It is an interesting footnote to these developments that in 1929 borax production at the Atacama and Antofagasta districts of Chile, which had fallen from 39,025 tons in 1925 to 16,746 tons in 1928, was abandoned because competition with California production was not profitable.<sup>103</sup>

## REFERENCES

1. *Ind. Eng. Chem.* 20, 991 (1928).
2. *O.P.D. Repr.* 67 (Nov. 28, 1927).
3. P. M. Tyler, Bur. Mines, *Inform. Circ.* No. 6833, 16 (1935).
4. *Eng. Min. J.* 120, 863 (1925).
5. *Min. Ind.* 1920, 634.
6. *Ibid.* 1921, 639.
7. *O.P.D. Repr.* 49 (Apr. 7, 1930); *Haynes Chemicals Directory*, 1939; Tyler, *op. cit.*
8. *Am. J. Sci.* (5) 5, 65 (1923).
9. G. J. Young, *Eng. Min. J.* 124, 98 (1927).
10. R. H. Polack, Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. I, Jan. 9, 1929, p. 678.
11. *O.P.D. Repr.* 21 (Dec. 8, 1930).
12. Hearings, *op. cit.*, Mar. 2, 1929, p. 9625.
13. Co. memo to author.
14. *Chem. Mkts.* 20, 209 (1927).
15. R. H. Kerr, C. T. N. Marsh, W. F. Schroeder, and E. A. Boyer, *J. Agr. Research* 33, 541 (1926).
16. *Drug. Chem. Mkts.* 17, 20 (1925).
17. Tariff Comm., *Report on Potassium Chlorate*, 1925, p. 3.
18. *Drug Chem. Mkts.* 13, 1388 (1923).
19. Tariff Comm., *op. cit.* p. 1.
20. C. H. Penning, *Chem. Met. Eng.* 46, 79 (1939).
21. Hearings, *op. cit.*, Jan. 7, 1929, p. 151.
22. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929 (H.R. 2667), Sched. 1, June 14, 1929, p. 417.
23. J. P. Brownstead, E. T. Edwards, E. E. Smith, and C. P. Hoover, Ohio Conf. Water Purif., *Ann. Rept.* 1925, p. 31; *Chem. Mkts.* 28, 279 (1931).
24. C. S. Hollander, *Am. Dyestuff Repr.* 12, 10 (1923).
25. H. Freeman, *Can. Chem. Met.* 9, 151

\* T. M. Cramer, U. S. Pats. 1,678,381 and 1,685,214 (1928), asst. to Pacific Coast Borax Co.

- (1925); Freeman and Canada Carbide Co., Brit. Pat. 211,488 (1924).
26. L. Litchfield, Jr., *Chem. Ind.* 48, 156 (1941); *Min. Res.* 1929, I, 489.
27. *Drug Chem. Mkts.* 12, 915 (1923).
28. *Min. Ind.* 1923, 28.
29. *Ibid.*
30. *Ibid.* 30; 1924, 37; 1925, 35.
31. *Ibid.* 1924, 38.
32. W. L. Savell, to author, May 10, 1946; A. Merz and K. H. Klipstein, *ibid.* May 21, 1946; Rogers' *Industrial Chemistry*, 6th ed., I, 461.
33. M. H. Haertel, *Chem. Met. Eng.* 36, 687 (1929); P. H. Groggins, *Ind. Eng. Chem.* 23, 152 (1931).
34. Groggins, *Chem. Met. Eng.* 36, 742 (1929).
35. A. E. Dunstan, F. B. Thole, and F. G. P. Remfry, *J. Soc. Chem. Ind.* 43, T179 (1924).
36. *Min. Ind.* 1923, 37.
37. *Chem. Met. Eng.* 34, 586 (1927).
38. *Ibid.* 37, 16 (1930).
39. Co. memo to author.
40. *Chem. Mkts.* 23, 389 (1928).
41. E. C. Thompson, to author, May 16, 1946.
42. *Min. Ind.* 1924, 43.
43. *Ibid.* 39.
44. Tariff Comm., *Report on Barium Carbonate*, 1928.
45. *Drug Chem. Mkts.* 10, 567 (1922).
46. *Ibid.* 12, 143 (1923).
47. J. G. Harrison, to author, May 14, 1946; *Drug Chem. Mkts.* 12, 1615 (1923); *O.P.D. Repr.* 18 (June 25, 1923); W. Haynes, *Chem. Ind.* 35, 205 (1934).
48. *Chem. Met. Eng.* 37, 42 (1930).
49. *Drug Chem. Mkts.* 14, 10 (1924).
50. *O.P.D. Repr.* 36 (Nov. 21, 1927); *Min. Ind.* 1927, 56.
51. *Eng. Min. J.* 129, 131 (1930).
52. *Min. Ind.* 1929, 62; Tariff Comm., *Report on Barium Carbonate*, 1928.
53. Tariff Comm., *Report on Barium Carbonate*, 1928.
54. *Ibid.*; *Min. Ind.* 1926, 83.
55. Tariff Comm., *Report on Barium Carbonate*, 1928.
56. *Min. Ind.* 1927, 56; *Chem. Mkts.* 22, 283, 417 (1928).
57. *Drug Chem. Mkts.* 12, 793 (1923); Tariff Comm., *Report on Barium Dioxide*, 1924.
58. *Drug Chem. Mkts.* 18, 1159 (1926).
59. Hearings Ways & Means Comm., *op. cit.*, Mar. 11, 1929, p. 9692.
60. *Ibid.*
61. R. W. Stone, "Magnesite," in Spurr and Wormser, *Marketing of Metals and Minerals*, p. 400.
62. Tariff Comm., *Report on Magnesite*, 1928.
63. *Ibid.*; *Chem. Mkts.* 21, 703 (1927).
64. *Min. Ind.* 1929, 418; Tariff Comm., *Report on Magnesite*, 1928.
65. Co. memo to author.
66. *Min. Res.* 1929, II, 136.
67. *Ibid.* 1923, II, 18; *Min. Ind.* 1923, 430.
68. *Fortune* 112 (Dec. 1942).
69. J. A. Gann and A. W. Winston, *Ind. Eng. Chem.* 19, 1193 (1927).
70. Gann, *Chem. Mkts.* 30, 335 (1932).
71. *Ibid.*; W. C. McIndoe, *Chem. Ind.* 49, 163 (1941).
72. Dow Chemical Co., *Ann. Rept.*, May 31, 1941, reprinted in *Ind. Eng. Chem., News Ed.* 19, 993 (1941).
73. *Ind. Eng. Chem.* 19, 776 (1927).
74. U. S. Pat. 1,581,188 (1926); *Chem. Met. Eng.* 32, 595 (1925). See also Mantell, *Industrial Electrochemistry*, p. 197.
75. *Chem. Mkts.* 19, 440 (1926); *Min. Ind.* 1926, 102.
76. *Min. Ind.* 1927, 78; *Min. Res.* 1927, I, 309; *Chem. Mkts.* 21, 45 (1927); *Chem. Met. Eng.* 34, 449 (1927).
77. *Chem. Mkts.* 21, 184 (1927); 24, 68 (1929).
78. Co. memo to author.
79. *Chem. Mkts.* 28, 269 (1931).
80. *Iron & Coal Trades Rev.* 120, 238 (1930).
81. *O.P.D. Repr.* 46 (Aug. 12, 1929); orig., H. A. Doerner, Bur. Mines, *Rept. Invest. No. 2999* (1930).
82. Hearings Ways & Means Comm., *op. cit.*, Jan. 7, 1929, p. 32.
83. *Min. Res.* 1923, I, 113; *Min. Ind.* 1923, 109.
84. *Min. Ind.* 1925, 125.
85. *Ibid.* 1929, 72.
86. *Ind. Eng. Chem.* 24, 394 (1932).
87. *O.P.D. Repr.* 50 (Apr. 3, 1933).
88. *Ibid.* 31 (Dec. 9, 1929).
89. J. G. Vail, *Chem. Met. Eng.* 35, 47 (1928), 37, 17 (1930); *Chem. Mkts.* 21, 579 (1927).
90. *Chem. Mkts.* 20, 42 (1927).
91. Co. memo to author.

92. *Chem. Mkts.* 23, 495 (1928); 25, 186 (1929).  
93. Co. memo to author.  
94. *Min. Ind.* 1924, 254.  
95. *Ibid.* 1925, 274.  
96. *Ibid.* 1929, 66; *O.P.D. Reprtr.* 49 (Apr. 7, 1930).  
97. *Wall St. J.*, Aug. 14, 1928, quoted in *Ind. Eng. Chem.* 20, 992 (1928); *Chem. Mkts.* 22, 642, 657, 658 (1928).  
98. G. R. Robertson, *Ind. Eng. Chem.* 21, 520 (1929); *Min. Ind.* 1927, 65; *Chem. Mkts.* 22, 644 (1928).  
99. Co. memo to author; *Chem. Mkts.* 22, 645 (1928).  
100. *Min. Ind.* 1926, 90, 1927, 65; *Chem. Met. Eng.* 34, 264 (1927).  
101. *Chem. Mkts.* 20, 222 (1927).  
102. *Chem. Met. Eng.* 35, 44 (1928).  
103. *O.P.D. Reprtr.* 58 (May 20, 1929).





*PART THREE*  
ORGANIC CHEMICALS



## Chapter 10

### ALCOHOL UNDER PROHIBITION

INDUSTRIAL ALCOHOL SUFFERS UNDER ARBITRARY ENFORCEMENT AND CHANGES IN DENATURED FORMULAS—AGITATION AGAINST POISONOUS METHANOL: ALDEHOL OBLIGATORY IN CD FORMULAS AND HARMLESS DENATURANTS SOUGHT—DORAN REPLACES HAYNES IN NEW PROHIBITION BUREAU—SWITCH TO MOLASSES CLOSES MANY MIDWEST DISTILLERS AND MERGERS CONCENTRATE OUTPUT IN U.S.I., AMERICAN SOLVENTS, AND AMERICAN COMMERCIAL ALCOHOL COMPANIES—SYNTHETIC ALCOHOL AND NEW SOLVENTS INVADE THE INDUSTRY.

**A**T THE CHEMISTS' CLUB "round table" in New York, during the reign of Roy A. Haynes as Federal Prohibition Commissioner, Burnell Tunison exploded once to a group of his friends. "Alcohol," he exclaimed bitterly, "is no longer a beverage, a solvent, or a chemical; it's a distillation of politics denatured with the unadulterated essence of prejudice."

Alcohol makers and legitimate industrial users all agreed wholeheartedly with this caustic definition. Government regulation was no novelty. For centuries alcohol had been loaded with excise taxes which had raised its price and restricted its sale to cost-immune uses in vital medicines and luxury cosmetics. But the high war tax was continued long after most of these revenue-raising duties had been removed, and efforts to enforce Prohibition had hedged ethyl alcohol about with rules and penalties as stringent as those controlling cocaine. This was expensive and inconvenient, but the real hardship to industry came in the restrictions on the use of denatured alcohol.

Tax-free alcohol, rendered unfit for beverage purposes, had been authorized by Congress twenty years before for the specific purpose of making this solvent more widely available for industrial use. The Prohibition Law as passed recognized this. But the original bill, as written by Wayne B. Wheeler, head of the Anti-Saloon League, and introduced in the House by Volstead, completely ignored the existence of industrial alcohol or its tax-free status. When this significant omission was discovered, the alcohol industry hurriedly introduced a bill drawn by Milton C. Whitaker and James P. McGovern to save denatured alcohol. This proved to be good legislative tactics because the Prohibitionists could not ignore this bill, and fearing lest its passage would divide and

weaken the control they sought over alcohol in every form, they incorporated its salient provisions in Title III of the Volstead Act.<sup>1</sup>

Thus the purposes of the Prohibition Law were at the outset set forth clearly as not only to stop the sale of intoxicating beverages, but also to "insure an ample supply of alcohol and promote its use in scientific research and in the development of fuel, dye, and other lawful industries."\* Nevertheless, from the beginning administrators of the Volstead Act paid only lip-service to industrial alcohol. As time went on and the regeneration of denatured alcohol became at once more skillful and more flagrant, enforcement officials in desperation increasingly ignored the needs and overrode the rights of legitimate users of alcohol as a solvent and chemical.

Prohibition enforcement was logically placed in the Treasury Department where of all government bodies the Internal Revenue Bureau had the greatest experience with the problems which would obviously arise. It was logical, too, that Secretary Mellon should appoint a Prohibition Commissioner who was a stout Dry. Roy Haynes was an ardent Prohibitionist and as such had the political and moral support of the powerful Anti-Saloon League. From the industry's point of view he was not a happy selection. He had no technical training or business experience that would enable him to comprehend the chemical and economic problems involved. His temperance prejudices made it impossible for him objectively to fulfill the duty imposed upon him by the Congressional mandate to promote the scientific and industrial uses of alcohol.<sup>2</sup> As an executive he failed to measure up to the administrative size of his position, and when the rising tide of reconverted alcohol and smuggled liquors increased the pressure upon him, his judgment became more and more fanatical, his decisions more and more arbitrary.

Haynes was soon at loggerheads with the Secretary of the Treasury and the Commissioner of Internal Revenue. Andrew Mellon found Prohibition an irksome distraction from his more congenial and, as he thought, more important task of budget planning and tax reduction. David H. Blair, who because of the taxes involved felt it his duty to supervise industrial alcohol, frequently exercised his legal prerogative of reviewing the decisions and regulations of the Prohibition Unit, and he did not always see eye to eye with its chief.

Temperance supporters, masters of the art of political publicity,

\* "This was James P. McGovern's wording. He not only put it in the original Industrial Alcohol Bill, but he battled Volstead and Wheeler to see that this wording stayed in the Bill. Incidentally, that wording was a great thorn in the side of the Prohibition people and was used effectively, as we expected it to be, by the industrial alcohol group. We have always felt that if that exact wording had not stayed in the law most anything might have happened to the users of industrial alcohol." (M. C. Whitaker, to author, June 5, 1946.)

launched a campaign of criticisms against the Treasury Department and introduced the Wood Bill \* to establish a Bureau of Prohibition answerable directly to the President, and to transfer to it all powers exercised by the Secretary of the Treasury and Commissioner of Internal Revenue. At public hearings held by the House Judiciary Committee, this measure was strongly opposed by scientific and medical societies and trade organizations as inimical to the best interests of the country because it would create a powerful bureaucracy that has no place in American government. A. Homer Smith, secretary of the American Drug Manufacturers' Association, on its behalf and that of the National Drug Trade Conference, filed briefs pointing out how impossible it would be for the President to devote the time necessary for the proper supervision of Prohibition enforcement. He cited a number of specific instances in which the Commissioner of Internal Revenue, after full and open hearings, had modified or rescinded unreasonable, captious orders of the Prohibition Commissioner.<sup>3</sup>

This measure died in committee. Next year its provisions were revived in the Cramton Bill, with the notable exception that the newly created Bureau of Prohibition would be directly under the Secretary of the Treasury, thus sidestepping the jurisdiction of the Commissioner of Internal Revenue. This bill passed the House, June 5, 1924.† Because it would relieve him of uncomfortable burdens, Commissioner Blair gave this bill tacit approval, and though it did not get to the floor of the Senate that session, nevertheless its chance of passage appeared excellent. During the recess, however, the opposition rallied and at the hearings of the Judiciary Committee presented impressive arguments against putting control of industrial alcohol unreservedly in the hands of the Prohibition Unit.‡ The Cramton Bill was reported out to the Senate where it was killed, March 2, by a filibuster led by Senators Edwards and Bruce.<sup>4</sup>

This bill proved to be a boomerang. Testimony at the hearings disclosed such willful and unfair methods § in administering industrial

\* H.R. 12035; an identical bill was introduced by Sen. Ernst of Kentucky (S. 3713).

† For an excellent review of this legislation from the chemical point of view, see W. L. Crounse, *Drug Chem. Mkts.* 16, 1173 (1925).

‡ This opposition was spearheaded by the various technical and commercial associations banded together in the Allied Comm. of Alcohol Users which included Am. Chem. Soc. and Am. Inst. Chem. Engrs., represented by Dr. Martin H. Ittner; Synth. Org. Chem. Mkrs. Assoc., P. Samuel Rigney; Mfg. Chem. Assoc., Dr. Chas. L. Reese; Ind. Alcohol Mkrs. Assoc., James P. McGovern; Nat. Wholesale Drug. Assoc., Wm. L. Crounse; Am. Mkrs. Toilet Articles, John A. Handy; Nat. Oil, Paint & Varnish Assoc., H. S. Chatfield; Flavoring Ext. Mkrs. Assoc., R. H. Bond; Artificial Silk Mkrs. Assoc., Roland L. Taylor. (See *O.P.D. Repr.* 19, Mar. 9, 1925.)

§ One regulation made it illegal to accept cash payments for delivery of alcohol, thus making the legal tender of the U. S. illegal.

alcohol that Secretary Mellon ordered a complete reorganization. Administration was placed under special Assistant Secretary General Lincoln C. Andrews, a retired Army officer, who promptly put himself on record as favoring scrupulous protection of the interests of legitimate alcohol users.<sup>5</sup> In his hands were placed the former duties of the Bureau of Internal Revenue and of the Coast Guard units detailed to prevent liquor smuggling. The country was divided into 22 districts, each under a Prohibition administrator vested with full authority and held responsible for law enforcement within his jurisdiction. He was given an assistant for enforcement, a chemist, legal counsel, and trained investigators. Most important, he had another special assistant with a staff of trained chemists and pharmacists to handle alcohol for legitimate purposes.<sup>6</sup>

Throughout this troublesome period, the Alcohol Trades Advisory Committee, organized June 1, 1923,<sup>7</sup> served as a buffer between Commissioner Blair and Prohibition Administrator Haynes. It also performed a useful service in bringing into the open fly-by-night concerns which were diverting denatured alcohol into bootlegging channels under the guise of being legitimate industrial consumers. Its chairman was William A. Sailer \* of Sharp & Dohme, president of the American Drug Manufacturers' Association; its secretary was Harrison E. Howe, editor of *Industrial & Engineering Chemistry*. Serving with them were William J. Schieffelin, National Wholesale Druggists' Association; Martin H. Ittner, American Manufacturers of Toilet Articles; Frank A. Blair, Proprietary Association; R. H. Bond, Flavoring Extract Manufacturers' Association; Milton C. Whitaker, U. S. Industrial Chemical Company; Charles L. Reese, Manufacturing Chemists' Association; R. M. Kane, American Pharmaceutical Manufacturers' Association; Samuel C. Henry, National Association of Retail Druggists; and Dr. James H. Beal, American Pharmaceutical Association.

One of the first tasks of this committee was to study the regulations covering nonbeverage alcohol and to make recommendations which, while not weakening enforcement, would lighten the burden of industrial users.<sup>8</sup> It secured an important modification in permits issued to plants engaged in the manufacture of alcohol. The Prohibition Unit had added to these permits a drastic condition providing for inspection at any time of day or night by any Prohibition or revenue agent or police officer. Upon the recommendation of the committee this was modified to read "during business hours."<sup>9</sup>

\* Prior to going with Sharp & Dohme, of which he was one of the largest stockholders, Sailer was secy. and gen. mgr. of John Wyeth & Bro. (1894-1909). During World War I he was on the Drugs War Service Comm. and for 2 yrs. headed the Baltimore Drug Exchange. He was born in Paulsboro, N. J., Nov. 4, 1861, and died in Baltimore at the age of 75.

Capricious administration of the Prohibition Law kept the legitimate trade in a turmoil. The excellent reorganization of the enforcement forces had hardly been completed before General Andrews, without consulting manufacturers or consumers of industrial alcohol, or conferring with the Alcohol Trades Advisory Committee, asked the Ways and Means Committee to levy a tax of a cent a gallon on denatured alcohol.<sup>10</sup> Contrary to the whole idea of tax-free, nonbeverage spirits, this proposal was made on the grounds that, as he himself said, it would "give us excise supervisory authority so that we may control better the uses of denatured alcohol." A witness at the subsequent hearings characterized the proposal as "chaining all the dogs to catch the sheep-killing dog."

This suggested indirect control never passed the Congressional committee, but there was no such check upon arbitrary changes in denaturing formulas that frequently upset chemical processing operations in many industries and sometimes threw the chemical market out of balance. For example, in 1926 the Prohibition Administrator suddenly canceled formula No. 6, calling for benzene, and substituted No. 5. This eliminated 250,000 gallons of benzene, at the same time creating a legal demand for a similar quantity of methanol just when the coal-tar intermediate was plentiful and when methyl alcohol was scarce due to the shutdown of many wood chemical plants because of the new synthetic competition.

Admittedly the ideal denaturant is methanol. Its close chemical and physical affinity to ethyl alcohol made it most acceptable for chemical uses and also most difficult to remove.

But methyl alcohol is poisonous, and an early sign of the growing revolt against Prohibition was a vigorous campaign, which started early in 1927, against the use of this deadly denaturant.

Rabid prohibitionists defended it, maintaining that whoever bought illicit liquor did so at his own risk. This callous argument fanned the resentment of many citizens. Secretary Mellon defended the use of methyl alcohol more logically.<sup>11</sup> In response to the resolution of Senator Edward Edwards of New Jersey, seeking information on the use of methanol and other poisonous denaturants, he declared that it was "the most effective means of accomplishing the requirements of the National Prohibition Act that denatured alcohol be unfit for use as an intoxicating beverage." He also emphasized its chemical importance. "The dye, artificial silk, paint, and other industries," he wrote, "as evidenced by their communications to the Treasury \* . . . feel that to remove wood

\* Among the chemical people who wrote were H. S. Chatfield, chmn. of the Ind. Alcohol Comm., Nat. Oil, Paint & Varnish Assoc.; Glenn Haskell, U. S. Industrial Alcohol Co.; Martin H. Ittner, Colgate & Co.; Starkweather & Williams, Inc., Providence, R. I.; H. E. Howe, ed., *Ind. Eng. Chem.*; and H. J. Schnell, ed., *O.P.D. Reprtr.*



alcohol as a denaturant in the present state of scientific knowledge would destroy them and would render impossible the duty imposed on the Treasury . . . requiring the Commissioner of Internal Revenue to promote such industries. . . . An effective denaturant not harmful if used for beverage purposes has not yet been found, although research is continued. The Treasury feels, then, that it has not the discretion, under existing law, to abandon an effective denaturant in favor of one not harmful but ineffective."<sup>12</sup>

Indignant protests against poisoned liquor filled the newspapers and piled high on the desks in Washington. Since no suitable substitute was available, an effort was made to make the poisonous denaturant give warning of its presence by adopting, January 1, 1927, a new formula specifying aldehyol \* in place of pyridine.<sup>13</sup> This new reagent was discovered by the Kay Research Company, a research group organized by Alfred G. Kay, head of a Pittsburgh brokerage firm, whose hobby was chemical experiments. Its small staff, Karl H. Fulton, M. T. Inman, W. P. Bitler, V. P. Ralli, Dr. Leonard Nicholl, and R. C. Poynton, operated an experimental plant and laboratory on Neville Island, near Pittsburgh, where they had for some time been trying to develop greases, resins, soaps, fatty acids, insecticides, and lacquer solvents, based on the oil-oxidation process and patents of Dr. Joseph H. James of the Carnegie Institute of Technology. These products, in spite of other desirable properties, were rejected universally because of their objectionable odor.<sup>14</sup>

While returning from another unsuccessful attempt to find markets, Fulton, who was chief chemical engineer of the company, casually discussed his troubles with a fellow train passenger who happened to be connected with the Prohibition Enforcement Bureau. He suggested that since the stuff smelled so badly, it might make a good alcohol denaturant and that the Bureau was always looking for such compounds. Upon his return to Pittsburgh, Fulton had samples prepared and as a forlorn hope submitted them to the laboratory of the Prohibition Enforcement Bureau in Washington.

Nothing was heard from these samples for a considerable length of time. Suddenly, however, the company was bombarded by telephone calls and wires from the Bureau. Kay was asked immediately to build a plant to produce 3,000 gallons of aldehyol a day. After several discussions concerning market guarantees, he agreed to go ahead with a commercial plant. Ground was purchased at West Nyack, N. Y., near Kay's

\* Not a definite chemical compound, but an oxidation product of kerosene which reacts similarly to an aldehyde. Specifications of the denaturing grade call for sp. gr. not over 0.825 at 60° F.; distillation range, 200-290° C.; 20% solubility in ethyl alcohol; an iodine no. not less than 35.

summer home, and by the end of four months a plant had been erected and was in production. The first commercial shipment of aldehol was made February 1, 1927.

Aldehol's place in denaturing formulas suddenly seemed to make it a very attractive commercial proposition. Kay incorporated the Kay Laboratories in Delaware with 2,500 shares of \$100 preferred and 5,000 shares of no-par common.<sup>15</sup>

Influenced by the pressure of the Government for quick action, it was decided to design a commercial plant directly from the initial laboratory setup. Since this was the first commercial venture in the manufacture of oxidized oil, there was no precedent to go on. Everything had to be designed to order. Therefore, in the beginning the plant proved to be a chemical engineer's nightmare.\* The crude material was hard to hold and on one occasion leaked into the water shed for northern New Jersey and polluted the drinking water of several New Jersey towns.<sup>16</sup> Despite these difficulties, including the Government's insistence that storage be maintained for a year's supply of the denaturant, the plant managed eventually to produce some 3,000 to 4,000 gallons a day.<sup>17</sup>

Aldehol's distinctive smell and nasty taste proved useful. Effective April 1, it became an obligatory ingredient in all completely denatured formulas,<sup>18</sup> and a month later the Prohibition Commissioner ordered that all alcohol of the rescinded formulas 2, 3, 4, 6, and 7 in quantities of more than one drum, must be denatured by addition of this reagent before it could be sold.<sup>19</sup> By the middle of summer it was announced that, thanks to better administration and use of alcohol, less industrial alcohol was being diverted to beverage use than at any time since the passage of

\* "During this time there was considerable misinformation printed in the papers by various groups to discredit aldehol and to get it tossed out of the formula. It was all part of the game and aldehol *was* vile smelling stuff. Our most dramatic remembrances were the difficulties in erecting a commercial operation to produce oxidized oil without going through the proper pilot-plant stage. We only did this because of the unusual pressure of the Government which developed after many weeks of procrastination on their part. One of our great difficulties was to find something that would hold the oxidized oil. It seemed to have the property of eating out everything it touched. As a result, we used to burn up three \$600 vacuum pumps a week and our aluminum condensers did not last much longer. It seemed as though the plant had to be practically rebuilt from week to week. This was, of course, before the days of stainless steel. As a result, the company was far from profitable, although first prospects looked quite rosy. We did manage, however, finally to make our expenses and reduced the price of the oxidized oil from \$1.00 a gallon to 70¢.

"We never did commercialize any of the solvents, greases, etc., that we were hunting for, but we did make a very good insecticide which, incidentally, we are still making by the same process. It does seem to illustrate one of the curious factors in the chemical business which I believe you called 'serendipity' in one of your books, after the mythical princesses of Serendip who were alleged to have traveled over the world looking for certain things, but came back with discoveries that were entirely different, but more valuable, than what they were originally seeking." (J. T. Ames, to author, June 7, 1946.)

the Volstead Law.<sup>20</sup> Nevertheless, the search for an even better denaturant and the juggling of denaturing formulas both continued.

Quick, unannounced changes in denaturing formulas, a favorite weapon of enforcement officials in their battle of wits against the alcohol regenerators, confused and embarrassed legitimate alcohol users. The shifting maze through which a couple of small lacquer companies stumbled pictures vividly the turmoil caused by this policy. When formula 3-A, for specially denatured alcohol in varnishes, lacquers, stains, polishes, disinfectants, and industrial liquid soaps, was rescinded January 1, 1927, the Lacquer & Chemical Corporation obtained a temporary injunction restraining the Treasury Department from the withdrawal of this formula.<sup>21</sup> Within a week this injunction, and a similar one obtained by the Great Northern Chemical Company, were dismissed and both firms were required to adopt the new formula.<sup>22</sup> During that year a number of specially denatured formulas,\* were approved for lacquers, thinners, etc., but effective December 15, all these were suddenly withdrawn and a new formula, 44-A, substituted. This required that to every 100 gallons of ethyl alcohol be added two gallons of gasoline and 10 gallons of either butyl alcohol, refined fusel oil, or amyl alcohol, synthetic or natural.<sup>23</sup> The following May 1, formulas 44-A and 23-A were suddenly substituted for Nos. 2-A, 2-B, and 12-A, in the manufacture of solvents of any kind except ethyl acetate and similar esters.<sup>24</sup> Regulations by the score, involving not only lacquers but artificial leathers, soaps, metal polishes, perfumes, cosmetics, and a host of other consumer goods, were issued overnight, changing formulas with no regard for their effect upon established process or products. The innocent bystander, the industrial user of alcohol, was shoved about unceremoniously, even beaten over the head, by both contestants in the alcohol melee.

Bootleggers and their customers, and thousands of honest citizens who hated and feared the lawlessness bred by Prohibition, continued to clamor for a nonpoisonous denaturant. The rabid Drys almost openly advocated a suicidal denaturant, but the Treasury Department put the discovery of a harmless reagent plainly up to those who recommended a change. Among many who entered this search for the ideal denaturant was the Industrial Alcohol Institute, Inc.,† which in 1927 founded an industrial fellowship for this purpose at Mellon Institute.<sup>25</sup> This organization, of which Lewis H. Marks became executive secretary in

\* Nos. 2-A, 2-B, 12-B, and 44.

† Organized in 1925 as the Ind. Alcohol Mfrs. Assoc., Inc.; name changed in 1928. First officers were: pres., Geo. F. Dieterle, Federal Products Co.; vice-pres., Sidney Klein, Kentucky Alcohol Corp.; treas., Lester S. Bacharach, Jefferson Distilling & Denaturing Co.; secy., Jos. Wrench, Industrial Chemical Co.

1927, had fourteen members which produced 97 per cent of the 85 million gallons of industrial alcohol set by the Government as the quota to be manufactured during 1928.<sup>26</sup> Although its Mellon Institute fellowship and the individual research of many of the companies in their own laboratories alike failed to find this much-sought ideal denaturant, nevertheless this organization did good work in cooperating with the Prohibition Unit to help unsnarl many technical tangles and also to keep denatured alcohol in legitimate trade channels and out of the hands of the bootleggers.

Confusion was worse confounded by a series of jurisdictional disputes within the Prohibition Unit. The hope of ardent friends of the Volstead Law that they might get enforcement out of what they considered the unsympathetic, restraining influence of the Treasury Department, sprang up time and again in efforts to create an independent Prohibition Bureau. Another move in this direction was made when Senator Couzens of Michigan introduced a bill in 1925 to transfer the Prohibition enforcement to the Department of Justice.<sup>27</sup>

On the other side, consumers of industrial alcohol urged that the administration of nonbeverage spirits be taken entirely out of the hands of the Prohibition Unit. This proposal was advanced by several witnesses at the hearings on the Cramton Bill during January 1925.<sup>28</sup> Dr. Milton C. Whitaker told the committee bluntly that in their handling of legitimate alcohol needs, Prohibition officials were ignorant and inefficient, or as Dr. Leo Baekeland phrased it, "Prohibitionists wear blinders and simply cannot see legitimate alcohol users."

Prohibition Commissioner Haynes was a target for both brickbats and bouquets. Even government officials criticized him for too great friendliness with Wayne E. Wheeler, the counsel, and other leading lights in the Anti-Saloon League. He was lauded by the Dry forces. Rumors of his resignation alternated with stories that his powers were to be extended.<sup>29</sup> Early in 1927, when the enforcement machinery was being overhauled, Haynes, actively supported by the Anti-Saloon League, was given a temporary appointment as Acting Commissioner of the new Prohibition Bureau.<sup>30</sup> Two months later, however, he was replaced by Dr. James M. Doran,\* with the understanding that all existing denaturing formulas were to be scientifically revised under his direction.<sup>31</sup> This appointment, as one of the chemical journals said,<sup>32</sup> "marks the end of a long fight by General Andrews and other Treasury officials against the domination of the Anti-Saloon League in Prohibition enforcement." The battle won, General Andrews resigned the following August and was succeeded by Seymour Lowman of Elmira, New York.<sup>33</sup>

\* Doran was succeeded as head of the Tech. Div., Bur. Internal Rev., by Wm. V. Linder.

This victory evidenced the rising resentment against the fanatical Prohibitionists, and it brought immediate relief to the industrial consumers by placing at the head of enforcement a chemist who recognized their needs and appreciated their technical problems. It had been a fixed tenet of the Drys that all Prohibition administrators and agents were honest and all makers and users of alcohol dishonest. They not only acted upon this fallacious premise, but they covered up any scandals involving enforcement officials while conducting a smear campaign aimed to stigmatize the industry as "a bunch of bootleggers." Such tactics roused resentment and many in the legitimate alcohol trade flatly refused to cooperate. If the purchaser's permits were in order, they would sell anyone, and by the time Prohibition was finally repealed Carbide and Carbon, du Pont, and Commercial Solvents were the only three ethyl alcohol producers which had not become involved in some sort of a diversion suit.<sup>34</sup>

As if the restrictions and distractions born of the Volstead Law were not enough to occupy fully the attention of alcohol manufacturers, the industry during these harassing years went through a whole series of critical changes. These affected its raw materials, its markets, and its organization. When the Eighteenth Amendment outlawed whisky many distillers converted to alcohol to preserve their plant investment. A sharp decline in alcohol price followed. The red tape that bound up its manufacture and sale further discouraged most of these experimenters so that by the middle of 1920, 22 plants with a daily capacity of 150,000 gallons had shut down.\* Many of these were in the Middle West; most of them did not reopen until Prohibition was repealed.

However, it was not Prohibition that closed these inland distilleries. The switch from corn to blackstrap molasses as the principal raw material of alcohol fermentation made these operations geographically uneconomical. In the face of Prohibition restrictions and competition from new solvents, the output of industrial alcohol † grew from 122 to 200 million proof gallons during 1923-29 to reach a total of almost two and a half times as great as prewar.

As the commercial history of alcohol has always been interwoven with excise laws, so its technical development has been invariably based upon the fact that it can be quite simply made by fermentation of any starchy or sugary materials. Accordingly its production in any country has always been based upon the cheapest, the most available of a wide variety of possible starting materials—grain, beets, potatoes, wine lees. During World War I, when grain was sorely needed as a foodstuff and freights were restricted, alcohol plants on the Atlantic seaboard turned

\* See Vol. III, p. 129.

† For U. S. production of denatured alcohol, 1923-29, see Appendix XXXII.

eagerly to by-product molasses from Cuba. They liked this raw material. It was cheap, economical to handle, and it eliminated the messy operation of mash cooking, with its subsequent problem of waste disposal. Although it takes two and a half gallons of blackstrap molasses (basis 52 sugars) to produce a gallon of alcohol (basis 190 proof), against two and a half gallons of alcohol from a single bushel of corn, still molasses has only a limited market as table sirup and stock feed additive, while the distillation plant is forced to compete for corn with mills and feed-lots.<sup>35</sup>

The Cuban Republic unwittingly dealt corn a body blow when, in an outburst of sanitary zeal, it passed an antipollution law forbidding cane planters to dump molasses in any stream. Spurred by war prices, Cuban sugar production leaped upwards and the island was literally oozing molasses which could not be dumped and which must be disposed of. Molasses buyers representing American alcohol companies coolly offered Cuban planters "a cent and a quarter a gallon, take it or leave it." Again the Cuban Government stepped in. To raise sugar prices, which had been depressed to ruinous levels, President Machado in 1927 restricted output to 4,500,000 tons. At 40 gallons of blackstrap to the ton of sugar, this gave an over-all output of only 180,000,000 gallons of molasses. The year before American alcohol distillers had consumed 267,000,000 gallons. The price of molasses jumped from 3 to 7 cents and called forth the first European shipment in years, 2,800,000 gallons from Holland and Poland to the Eastern Alcohol Corporation.<sup>36</sup>

The center of alcohol production having gravitated from Peoria to New Orleans, and molasses being no longer a waste by-product, control of this raw material became the key to competition among producers. It was the inspiring motive of many consolidations which by 1930 brought most of our alcohol output into the hands of three companies.

In the halcyon days when molasses could be purchased at salvage prices, only the U. S. Industrial Alcohol Company bought direct in Cuba. The other manufacturers secured this raw material chiefly through the British Molasses Company and the predecessor of the Old Time Molasses Company. When demand for blackstrap surpassed supply, the foresight of U.S.I.'s president, Horatio Rubens,\* in establishing

\* Rubens was a man of versatile capabilities. Born in New York, June 6, 1869, and educated at Coll. City of N. Y. (B.S., 1888; M.S., 1894) and Columbia (LL.B., 1891), he studied law in the office of Elihu Root. Specializing in Spanish-American affairs, he became counsel of Salvador, of the Cuban Junta during the revolt against Spain, of the Am. Insular Comm. in Puerto Rico, and the U. S. Mil. Govt. in Cuba. He was largely interested in various Cuban railroads and plantations and among many other honors was voted by the Cuban Congress the title of "The Great Friend of Cuba." When he retired as pres. of the U.S.I., Jan. 31, 1927, Rubens was succeeded by Russell R. Brown. He died Apr. 8, 1941.

the subsidiary Cuban Distilling Company to buy and transport molasses, put his company in a preferred position.

Hard-pressed by the molasses famine, other alcohol producers moved to assure this raw material. The Distillers Securities Corporation, original backer of U. S. Industrial Alcohol,\* which operated the Kentucky Alcohol Corporation and had taken over the Westwego plant of the American Alcohol Company in Louisiana, also took over in 1923 the Old Time Molasses Company. To make certain of supplies for their Berg and Publicker plants at Philadelphia, the Publicker brothers, Henry and Philip, organized the North American Molasses Company, which also operated directly in Cuba.<sup>37</sup>

After the passage of the Prohibition Law, the demand for molasses was further increased by two new alcohol plants established in New Orleans by Federal and Rossville. These and the other independent alcohol makers were supplied chiefly by two independent molasses companies. The first of these sold blackstrap from the raw sugar factories of the American Sugar Company, while the second, the Dunbar Molasses Company, was organized by men associated with the Old Time Molasses Company prior to its purchase by the Kentucky interests.

Attracted by the advantage of control over this now critical raw material and the brisk demand for anti-freeze alcohol, sugar companies also entered the field by stripping the so-called "refiners' molasses" from their plantation raw sugars. The Pennsylvania Sugar Company, which had made alcohol during the war, built a new refinery at Philadelphia, drawing molasses from the sugar estates of E. Atkins & Company, New York,<sup>38</sup> and creating a special alcohol division under Abbott K. Hamilton.† The Federal Sugar Company also built a distillery at Yonkers, New York, organizing a subsidiary, the Syrup Products Company, the sale of whose alcohol was placed in the hands of Roessler & Hasslacher.<sup>39</sup>

Molasses supply thus stood on a triangular, highly competitive base: direct control by alcohol companies and by sugar companies operating alcohol plants and independent supplies from outright molasses dealers. The most important factor in the last group was the United Molasses Company, Ltd., with headquarters in London, which was represented in the United States by the Dunbar Molasses Company. In 1929 United acquired the Old Time Molasses Company from the National Distillers' Products Corporation, successor of Distillers Securities.<sup>40</sup> Shortly after this purchase, because of its extensive interests in this country and Cuba, United Molasses set up an American board of directors consisting of

\* See Vol. III, p. 126.

† A Princeton graduate, Hamilton was the head of his own sales organization, A. K. Hamilton & Co., and when the Pennsylvania interests took over the Franco-American Chemical Works, 1929, he became its vice-pres. in charge of sales.

M. Levin, chairman of Dunbar; A. W. Loasby, president of Equitable Trust; C. U. Snyder of C. U. Snyder Company; and F. A. Rogers, president of the Eastern Alcohol Corporation.<sup>41</sup>

While the alcohol producers were scrambling to secure their share of blackstrap, friends of the Corn Belt farmers in Washington introduced a bill to raise the tariff on waste molasses to 20 cents a gallon.<sup>42</sup> This ingenious form of farm relief appeared again two years later when complete revision of the tariff was under Congressional consideration. Some Republican members of the House Ways and Means Committee frankly approved a duty sufficiently high to force the use of corn upon the alcohol industry, as was advocated by Dr. L. J. Norton, representing farmer-grain associations.<sup>43</sup> Industrial witnesses testified that any such uneconomic compulsion would defeat its own purpose. So high a duty, they pointed out, would simply serve as a subsidy to synthetic alcohol, which was already in production. Furthermore it would encourage the importation of alcohol derivatives and promote the use of glycerin, ethylene glycol, and other anti-freeze competitors.<sup>44</sup> Fortunately for the industry, which soon had to face all these new competitors, the industrial plea prevailed over the farm relief scheme.

It was also fortunate that the stresses and strains, political and economic, to which the alcohol industry was constantly subjected during the twenties, induced the small independent makers to band together in larger groups. Throughout these consolidations, the U. S. Industrial Alcohol Company continued to be the most important single producer, and in 1929, after the new Prohibition Commissioner, Dr. Doran, had set quotas for the production of industrial alcohol, this company was allowed roughly 40 per cent of the national total.<sup>45</sup> This position was held in part by mergers of its own, for in 1926 "U.S.I." took over the New Jersey Alcohol & Chemical Company \* of Newark, and the alcohol distillery of the Crystal Chemical Company in California.<sup>46</sup> A more important consolidation took place in 1929 when Kentucky Alcohol, subsidiary of the National Distillers' Products Corporation, was bought and its general manager, Sid Klein, became vice-president of U.S.I.<sup>47</sup> This purchase, affected by issuing 51,000 additional shares of no-par common stock, included the Westwego molasses plant; the Peoria grain plant, warehouse, and denaturing plant; and a bonded warehouse and denaturing plant at Louisville.<sup>48</sup> In 1927 the affiliation between the U. S. Industrial Alcohol and the Air Reduction Companies, dating back to 1920 when they had formed the Compressed Carbonic Company, and ce-

\* Organized in 1925 by E. B. Badger & Sons Co., Boston and the plant built to demonstrate a new still producing 192 proof alcohol by a continuous process. Output of this plant was sold by the C. P. Chemical Solvents, Inc., established in Nov. 1925 by Rolland H. French, an alcohol specialist with experience acquired at Miner-Edgar and Berg and Kentucky Alcohol Companies. (R. H. French, to author, May 24, 1946.)



mented by the Percy Rockefeller interest in both corporations, was made closer when Air Reduction paid cash for a minority interest in U.S.I.<sup>49</sup> and elected seven of its thirteen directors.\* This practical, working cooperation was further extended in 1929 when the two companies jointly acquired a substantial interest in the Pure Carbonic Company of America.<sup>50</sup>

In 1926 the first of the postwar consolidations was effected when the American Solvents & Chemical Corporation gathered together the Everett Distilling Company, the Jefferson Distilling & Denaturing Company, the Crescent Industrial Alcohol Company, the Western Industries Company, and the Witbeck Chemical Corporation.<sup>51</sup> The new corporation was manned with experienced alcohol men: H. I. Pfeffer † was president; A. P. Jell and B. R. Tunison, late of U.S.I., vice-presidents; and Lester S. Bacharach, ‡ secretary-treasurer. The financial setup of the new company was \$2,200,000 in 6½ per cent ten-year gold debentures, 160,000 shares of \$50 preferred stock, callable at 60 and paying 3 per cent (100,000 of which were presently sold) and 320,000 shares of no-par common, 160,000 of which were issued and 160,000 of which were held for conversion of the preferred.<sup>52</sup> Commenting on this merger editorially, *Drug & Chemical Markets* said, "The vast bulk of our alcohol production passes into three strong hands, enough to supply plenty of active competition for the price-benefit of buyers, and yet of sufficient stability and experience to maintain an even keel."<sup>53</sup> Three years later American Solvents expanded by acquiring the Cragin Products Company with a grain alcohol plant at Chicago, and January 1, 1930, by taking over the Rossville Commercial Alcohol and the General Industrial Alcohol Corporations.<sup>54</sup>

Both Rossville and General Industrial had themselves been created by mergers.<sup>55</sup> The former had been organized in Maryland, January 3, 1929, to acquire the Rossville Company, the Orange Grove Refining Company, Federal Products Company, Seaboard Chemical Company, the Industrial Chemical Manufacturing Company, with plants in New

\* Representing the Rockefeller interests were H. A. Arthur; S. F. Pryor of Owenoke Corp.; Guy Carey of Sherman & Sterling; F. B. Adams, chmn., Air Reduction; G. H. Walker, pres., W. A. Harriman & Co.; F. T. Bedford, Penick & Ford; and C. M. Adams, pres., Air Reduction.

† Pfeffer is a New Yorker by birth (Aug. 5, 1879) and education (C.C.N.Y.). From 1917-25 he was an officer of U. S. Industrial Alcohol Co. (gen. mgr., vice-pres.). When American Solvents consolidated with Rossville Commercial Alcohol in 1929, Pfeffer remained as pres. and chmn. He became bd. chmn. of Joseph E. Seagram & Sons and its subsidiaries in 1933, when these bought into the new company. He was treas. of the Distilled Spirits Code Authority and the Distilled Spirits Inst.

‡ Bacharach was a Jefferson man, being its Eastern representative, 1913-26, and serving as secy., General Alcohol Export Corp., 1915-18. He was born in Cincinnati, studied law at the U. there (LL.B., 1905) and practiced it till he entered the alcohol business.

Orleans, Cincinnati, Newark, and Mechanicsville, New York. Chairman of the board was Maurice Levin, formerly president of the Dunbar Molasses Company. President and moving spirit was Victor M. O'Shaughnessy,\* formerly the general manager of the Rossville and Orange Grove Companies. The General Industrial Alcohol Corporation had been incorporated in Delaware, in June 1929, to merge the assets of the General Industrial Alcohol, National Industrial Alcohol, Greendale, and Michigan Chemical Companies. It had a capitalization of \$2,500,000 preferred and 285,000 shares of no-par common. Later it also acquired the Molasses Distributors Corporation, which had recently bought out the domestic bulk blackstrap department of the American Molasses Company of New York.

The year American Solvents was formed, 1926, the Eastern Alcohol Corporation opened a plant at Deepwater Point, New Jersey. This was a jointly owned project of E. I. du Pont de Nemours & Company and the Kentucky Alcohol Corporation, subsidiary of the National Distillers' Products Corporation.<sup>56</sup> On the board du Pont was represented by H. Fletcher Brown, A. B. Echols, William Harris, and M. D. Fisher; while Kentucky interests were represented by Seton Porter, F. A. Rogers, and Thomas A. Clark.<sup>57</sup> The du Pont chemical operations, notably the dye plant adjacent to the new alcohol plant, had grown to a point where they were the largest single consumer of industrial alcohol in the country and this was the second joint venture of the sort.†

During 1928-29, the third great alcohol merger of this period took place when the American Commercial Alcohol Corporation acquired the assets of the American Distilling Company, David Berg Industrial Alcohol Company, and S. M. Mayer Alcohol Company.<sup>58</sup> Philip Publiker, president of Berg, and Richard H. Grimm,‡ president of American Distilling, who effected this consolidation, became respectively chairman and president of the new company. The company moved aggressively into the West Coast territory where it organized the American Commercial Alcohol Company of California, purchasing and merging with its subsidiary, the International Solvents Company of San Francisco.<sup>59</sup> Three months later it acquired the Orleans Distilling Company and in September reached out into the allied field of organic solvents and plasticizers by buying the Kessler Chemical Corporation of

\* O'Shaughnessy and his younger brother, Eugene A., came from one of the old distillery families of Kentucky. Both were born in Newport, Ky., and educated at St. Xavier Coll., Cincinnati.

† For details of the du Pont-Standard Alcohol operation at Georgetown, S. C., see Vol. III, p. 124.

‡ Born in Desplaines, Ill., Grimm went straight from high school in Chicago to the American Distilling Co., advancing during 25 yrs. through all ranks to mgr., Chicago office, 1921-24, then pres. till the consolidation.

Orange, New Jersey.<sup>60</sup> This successful specialty enterprise had been started in 1920 by Dr. John M. Kessler,\* who became a vice-president of the parent alcohol corporation and remained president in active charge of its subsidiary, with his old production manager, Dr. O. B. Helfrich,† as vice-president.

A similar excursion into the solvents field was made at about the same time by the Pennsylvania Sugar Company. It took over a controlling interest in the Franco-American Chemical Works of Carlstadt, New Jersey, producers since 1900 of solvents and industrial and pharmaceutical chemicals.<sup>61</sup> Penn Sugar's vice-president, W. H. Hoodless, became president of Franco-American and its chemical genius, Moses Trubek ‡ continued as vice-president in charge of research and production.

These chemical ventures and the active development of U.S.I.'s subsidiary, the U. S. Industrial Chemical Company, and Publicker's new division making various acetates,<sup>62</sup> were natural reactions to the new solvents, plasticizers, and allied chemical products that began to infringe on the edges of the alcohol industry. These were years of great technical activity, the total domestic consumption of ethyl alcohol in chemical and related industries having reached an estimated total of 105,000,000 wine gallons in 1927.<sup>63</sup> The largest consumer was fine chemicals with 30,000,000 gallons; followed by paint and varnish, 7,600,000; explosives, 5,000,000; and coal-tar products, rayon, and leather with 2,000,000 each.

At this time, alcohol motor fuel blends were being eagerly discussed. Panama ordered 5 per cent alcohol in its motor fuel to encourage the sugar industry,<sup>64</sup> and from Germany came the story of an enormous plant built to produce anhydrous alcohol, according to the Société Ricard, Allenet patents.<sup>65</sup> In this country, the availability of gasoline made such blends uneconomic though road tests showed their operating practicality.<sup>66</sup>

The anti-freeze market which had made alcohol a big-tonnage commodity continued to expand, and in 1926, sensing the growing competition from glycerin and ethylene glycol, the Industrial Alcohol Manufacturers' Association coined the word "Freez Foil" and started

\* German-born and trained at Heidelberg and Munich (Ph.D., 1906), Kessler went first with J. D. Riedel—E. de Haën, and coming to this country, was with du Pont from 1910 to 1920.

† Helfrich remained with Kessler till 1933, when he became tech. sales representative of the Resinous Products & Chemical Co. He was born in Maryland, Aug. 14, 1897, and earned his Ph.D. at Johns Hopkins in 1920, having previously been chem. with the Bur. Mines and serving as 2d Lt. in Chem. Warfare Serv. He was with du Pont a year before joining Kessler.

‡ One of the earliest U. S. mfrs. of ethyl chloride on a commercial scale, Trubek was born in Riga, Latvia, in 1868, and received his Ch.E. degree from the famous university of his native town. Before going into business for himself he was chem. for several leather and sugar companies.



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the first cooperative advertising campaign in daily newspapers and farm journals.<sup>87</sup> Their attention riveted upon this growing business and diverted by the harassments of Prohibition enforcement, alcohol executives hardly noticed the appearance of synthetic alcohol and paid but little attention to the growth of butanol and the birth of a whole phalanx of new organic solvents and plasticizers.

## REFERENCES

1. M. C. Whitaker, to author, June 5, 1946; J. P. McGovern, *ibid.*, June 4, 1946.
2. *Ind. Eng. Chem.* 15, 1198 (1923).
3. *Ibid.*, *News Ed.* 5 (Feb. 20, 1923); *Drug Chem. Mkts.* 12, 537 (1923).
4. *Ibid.* 16, 429, 433 (1925); *O.P.D. Repr.* 5 (Mar. 26, 1925); *Drug. Circ.* 69, 132 (1925).
5. D. H. Killeffer, *Ind. Eng. Chem.* 17, 996 (1925); *Drug Chem. Mkts.* 16, 1036 (1925).
6. *Drug Chem. Mkts.* 17, 23, 231, 283, 299, 351 (1925).
7. *Ibid.* 12, 1117 (1923); *Ind. Eng. Chem., News Ed.* 1 (June 10, 1923); *Drug. Circ.* 66, 296 (1923).
8. *O.P.D. Repr.* 59 (June 11, 1923); *Drug Chem. Mkts.* 13, 275 (1923).
9. *Chem. Met. Eng.* 29, 1155 (1923).
10. *Ibid.* 32, 841 (1925).
11. *Chem. Mkts.* 20, 49 (1927).
12. *O.P.D. Repr.* 21 (Jan. 17, 1927); see also M. H. Haertel, *Chem. Ind.* 40, 241 (1937).
13. *Chem. Mkts.* 19, 942 (1926).
14. J. T. Ames, to author, June 7, 1946; *O.P.D. Repr.* 46B (Jan. 3, 1927); Killeffer, *Ind. Eng. Chem.* 19, 1079 (1927); *Chem. Met. Eng.* 35, 326 (1927).
15. *Chem. Mkts.* 20, 503, 610 (1927).
16. *Drug Mkts.* 20, 200 (1927).
17. *O.P.D. Repr.* 38B (Feb. 21, 1927).
18. *Chem. Met. Eng.* 34, 265 (1927).
19. *Chem. Mkts.* 20, 713 (1927).
20. *Chem. Met. Eng.* 34, 515 (1927).
21. *Chem. Mkts.* 20, 49 (1927).
22. *Ibid.* 141.
23. *Ibid.* 21, 741 (1927).
24. *Ibid.* 22, 532 (1928).
25. *Ind. Eng. Chem.* 19, 38 (1927); *Chem. Met. Eng.* 34, 125 (1927).
26. *Chem. Mkts.* 22, 590 (1928); *Chem. Met. Eng.* 35, 588 (1928).
27. *Drug Chem. Mkts.* 16, 813 (1925).
28. *Ibid.* 113.
29. *Ibid.* 199.
30. *Ibid.* 20, 495 (1927).
31. *Ind. Eng. Chem.* 19, 756 (1927); *Chem. Met. Eng.* 34, 391 (1927).
32. *Chem. Mkts.* 20, 803 (1927).
33. *Drug Mkts.* 21, 21 (1927).
34. J. G. Park, to author, July 11, 1946.
35. *Chem. Mkts.* 19, 1275 (1926).
36. *Ibid.* 20, 321 (1927); *Ind. Eng. Chem., News Ed.* 14, 375 (1936).
37. *Ibid.* 19, 1276 (1926).
38. *Drug Chem. Mkts.* 16, 283 (1925).
39. *Chem. Mkts.* 20, 463 (1927).
40. *Ibid.* 26, 65 (1929).
41. *Ibid.* 295.
42. *O.P.D. Repr.* 21 (Jan. 31, 1927), 36 (Feb. 21, 1927); *J. Am. Pharm. Assoc.* 16, 492 (1927).
43. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 5, Jan. 22, 1929, p. 2441.
44. *O.P.D. Repr.* 76 (Apr. 29, 1929).
45. *Chem. Mkts.* 36, 143 (1930).
46. *Ibid.* 19, 579 (1926); *Moody's Manual of Investments, Industrials, 1940.*
47. *Poor's Manual of Industrials, 1930; Chem. Mkts.* 25, 65, 181 (1929).
48. *Com. Fin. Chron.* 128, 4338 (1929).
49. *Chem. Mkts.* 20, 463, 643 (1927); *Poor's, op. cit.*
50. *Moody's, op. cit.*
51. *Com. Fin. Chron.* 122, 3608 (1926); *Chem. Met. Eng.* 33, 320 (1926); *Drug Chem. Mkts.* 18, 1167 (1926).
52. *Chem. Mkts.* 19, 358 (1926).
53. *Drug Chem. Mkts.* 18, 1224 (1926).
54. *Chem. Mkts.* 24, 639 (1929); *Poor's, op. cit.*
55. *Chem. Mkts.* 24, 65, 627 (1929).
56. Co. memo to author; *Chem. Mkts.* 19, 529 (1926).
57. *Drug Chem. Mkts.* 17, 1473 (1925).

58. *Chem. Mkts.* 22, 529 (1928); *O.P.D. Repr.* 64 (July 23, 1928).  
59. *Chem. Mkts.* 24, 405 (1929).  
60. *Ibid.* 25, 73, 297 (1929).  
61. *Ibid.* 24, 293 (1929).  
62. *Ibid.* 21, 455 (1927).  
63. *Chem. Met. Eng.* 34, 587 (1927).  
64. *Drug Chem. Mkts.* 18, 1091 (1926).  
65. *O.P.D. Repr.* 61 (July 30, 1928).  
66. Whitaker, *Drug Chem. Mkts.* 17, 981 (1925).  
67. *Ibid.* 19, 1025 (1926).

## Chapter 11

### WOOD CHEMICALS MEET SYNTHETIC COMPETITION

GERMAN SYNTHETIC METHANOL AT 45¢ A GALLON COUNTERED BY HIGHER DUTY; USE OF NATURAL METHANOL IN DENATURED ALCOHOL; FEWER, BIGGER PLANTS; NEW TECHNICAL AND SALES METHODS—DOMESTIC SYNTHETIC OUTPUT FROM COMMERCIAL SOLVENTS AND DU PONT—BREWSTER AND SUIDA PROCESSES ADOPTED TO COMPETE WITH SYNTHETIC ACETIC ACID—WOOD CHEMICAL INSTITUTE UNDERTAKES EDUCATION AND RESEARCH.

THE AMERICAN WOOD CHEMICAL INDUSTRY was dead, dead as Scrooge's partner, Old Marley, and nobody expected its ghost to rise. Its messy, little plants might as well be scrapped; its stockpiles sold off; its affairs wound up as quickly and economically as possible. That was the 1925 verdict, when in the single month of February, 62,971 gallons of synthetic methanol were landed in New York from Germany and offered to astonished and obviously delighted consumers at 45 cents a gallon, duty paid.<sup>1</sup> This was 28 cents under the price asked by the average American wood chemical producer.<sup>2</sup>

Knowing the Germans of old, nobody doubted that they could slash the price of synthetic methanol deeper, nor that they would hesitate to do so if it served their purpose. Just to drive a nail in the coffin of the American industry, chemically conscious Trade Commissioner Daugherty reported from Berlin that the current production of synthetic methanol at the great Leunawerke plant of Badische was a thousand tons monthly and that plans to double it immediately had been approved.<sup>3</sup>

It was as plain as two plus two that the American wood distiller, who for years had ruled over world markets for the methyl group of chemicals, was destined to furnish another dramatic episode in the victorious war that chemical synthesis was waging against the slower, more clumsy processes of nature. Soon, so everyone believed, wood alcohol and acetate of lime would join sour milk and the indigo plant in the museum of chemical relics.\*

As is chemical custom, nobody wasted sympathy on the doomed industry. Its customers welcomed the synthetic product, grateful for its lower price, delighted at its greater purity. Its contemporaries in other divisions of chemical industry faced the facts with callous realism. They

\* For a good general description of the chemical utilization of wood, see H. K. Benson, Dept. Com., Nat. Comm. Wood Utilization, *Rept. No. 22* (1932).



were hardened to such technical revolutions. Many of them had battled desperately to avoid just such catastrophies and they observed rather heartlessly that wood distillation was an obsolete process, and that was that. It became fashionable to pillory the wood distiller as a horrible example of what happens to an industry that neglects research. Invidious comparisons were made between its primitive little plants and the great copper and stainless steel monuments of modern chemical engineering skill from which pure methanol poured in an ever-increasing stream. Few credited the wood distiller with having for years turned the wastes of lumbering into valuable chemicals or explained that his primitive technique and antiquated sales methods had been governed by economic conditions largely beyond his control. Nobody had the faith to believe that this outmoded industry could gather itself together, adopt modern methods, and rise phoenix-like from the ashes of its own technological ruin.

There was, in faith, little reason for any such optimistic convictions. The industry was scattered and the typical plant small and inefficient, but a great deal of money had been made out of these operations. Enjoying a real monopoly of methanol, acetate of lime, and charcoal, the wood distillers had made little effort to improve their processes or to reduce their costs. Most of the conversions to modern practice savored of deathbed repentances, and salvation was found only by bringing over processes that had been perfected in Europe. But the fact remains that, upsetting all the funeral arrangements, the corpse of this industry simply refused to stay dead.

The blow of synthetic competition fell like the blade of a guillotine. Yet for several years there had been threatening rumors of such a process being perfected in Europe. The suggestion of the great French chemist, Paul Sabatier, made in 1905, that methanol might be synthesized from carbon monoxide had set a number of Continental investigators to work on this problem.<sup>4</sup> The war interrupted these researches, but with the return of peace, they were taken up with fresh gusto.

M. Patart of the French Bureau of Explosives had carried on the negotiations with Badische for the purchase of the Haber process. Fascinated by the pressures involved in ammonia synthesis, he conceived the idea that these same principles might facilitate the synthesis of methanol from carbon monoxide and hydrogen, a reaction which at normal pressures results in the formation of methane and water.\* His expecta-

\* Patart's process was based upon the principles of van't Hoff and Le Châtelier's laws that displacement of the equilibrium point would be favored, in this case by increased pressure, and that the same catalysts which accelerate splitting a compound into its components will also accelerate the reformation of the same compound. His patent claimed as catalysts all metals and their oxides and salts known to favor oxidations and

tions worked out successfully and he was granted French Patent, 540,543, August 19, 1921. Though several other chemists, including Sabatier himself and Calvert in England, had claimed to have obtained methanol from this same synthesis, Patart's patent was the first official claim of a workable method. It purports to disclose six types of reactions, only one of which is workable, and that one only if one discovers a catalyst which is not disclosed in the patent. The Patart process was never a commercial success, although with the financial backing of the French Ministries of War and Commerce, a semiplant operation was set up near Paris in 1922.

All this time the Germans had been ominously silent. But they had not overlooked either the chemical or the commercial potentialities of synthetic methanol. As far back as 1916 they had taken out a blanket patent \* for "compounds containing carbon and hydrogen," so broad that it embraced almost the entire field of the synthetic production of alcohols.<sup>5</sup> While the French were building their experimental plant, Badische was rushing to completion a big-scale operation at Leunawerke. Some wild stories about this plant, its enormous capacity, and its very low costs, began leaking out of Germany during 1924.<sup>6</sup>

However much these stories might be discounted as propaganda, the project did make sense. It matched perfectly the pattern of German postwar chemical plans and conformed exactly to the logic of their chemical situation. While the I.G. had no intention whatsoever of limply surrendering the world's dyestuff market to its young competitors in Great Britain and this country, nevertheless it was straining to reach out into new fields: ammonia and concentrated plant foods, solvents and plasticizers, rayon and plastics, and synthetic fuels. With these products the Dye Trust planned to regain its lost position as cock of the chemical walk. The German need for exports to establish foreign credits, so great at this time that it amounted to a national crisis, could be relieved by exporting these new chemicals, and underlying the entire program was the tough, old problem of lacking raw materials.† Under

hydrogenations, and disclosed a temperature range of 300-600° C.; a pressure of 150-200 atm.

\* U. S. Pat. 1,201,850, issued Oct. 17, 1916, to A. Mittasch and C. Schneider, ass. to Badische, which was taken over by the Chemical Foundation and licensed either directly or indirectly during 1925, to Union Carbide, du Pont, Commercial Solvents, Mathieson Alkali, General Motors, General Electric, and one of the Standard Oil companies. [See *Chem. Met. Eng.* 32, 462 (1925).]

† This problem was not solved even at the end of World War II, when one of the American chemical engineers who inspected the plants and studied the records of the I.G. wrote, "Everything that we saw, everything that we read, revealed that the basic German chemical problem, and the aim of most of their research, was how to have a modern chemical industry without petroleum." (Walter J. Murphy, to author, Dec. 18, 1945.)

these circumstances synthetic methanol was an obligatory product. It was plain that the new chemistry would make great use of the methyl radical and Germany lacks both hardwood and methane to provide this versatile chemical group in the quantities needed.

Impressive evidence that this step in the German chemical program had been successfully consummated was presented to the American chemical industry in February 1925, with the landing of German synthetic methanol at New York. By May the total imports exceeded a quarter of a million gallons.<sup>7</sup>

The sudden appearance of sizable quantities of this important chemical at two-thirds the former quotation, created a turmoil. Consumers and producers were stunned. Buyers recovered promptly and scrambled to secure the low-cost material. The wood distillers hurried to Chicago to attend a special session of the National Wood Chemical Association. From their headquarters at Bradford, Pennsylvania, came a carefully worded statement, explaining their desperate position, blaming the I.G. for attempting to regain its lost domination of the chemical world by unscrupulous methods, endeavoring to rally popular support by emphasizing the economic importance of chemicals and the disastrous effects of the elimination of the American wood chemical industry.<sup>8</sup> Fat was thrown in the fire by rumors that Badische agents had come to this country to sell this revolutionary process to the highest bidder and that du Pont's ammonia subsidiary, Lazote, planned to embark on methanol synthesis.<sup>9</sup>

On May 6 a full attendance of the special committee of the National Wood Chemical Association gathered at Buffalo under Chairman William Matthews,<sup>10</sup> to hear the report of the special subcommittee headed by Dr. M. H. Haertel, assisted by S. H. Stilling and W. L. Heim.\* This report came to grips with the situation. It discounted the reported German costs as bait for the sale of the patent and estimated that with a 12 cent duty and 16-18 cent freight and drum costs, plus a selling commission, the Germans, to avoid exclusion under the Anti-Dumping Law, must allow at least 30 cents a pound for importation costs. It was noted that while sales here had been reported as low as 39 cents, the price in Germany was 50 cents.

The position of the average American producer was summarized in his yields from a cord of wood: 10 gallons of crude methanol at approximately \$4.50; 200 pounds of acetate of lime worth \$5.00; 50 bushels of charcoal worth \$7.00; a total of \$16.50 per cord. Providing the tariff of 12 cents a gallon was increased 50 per cent, the limit allowed by the

\* Besides these four, the special committee consisted of W. L. Saunders, W. J. Cumming, M. F. Quinn, W. J. Merwin, C. B. Hall, and W. Z. Georgia.

law, i. e., 18 cents per gallon, the report concluded that even if the Germans forced a 10 cents a gallon cut in pure methanol, it would mean a loss of only \$1.50 per cord, leaving a net gross sale of \$15.

The report was approved unanimously, and united by the common danger, every wood chemical producer in the country, 88 firms, joined in the petition to the Tariff Commission, requesting full increase in the duty, which was presented by their counsel, Thomas J. Doherty.<sup>11</sup> The Tariff Commission promptly ordered an investigation of domestic and foreign costs, which was completed during September 1925. However, it was not until June 1926 that public hearings were held.<sup>12</sup>

By this time the situation had so clarified that testimony at these hearings and especially the masterful *Report on Methanol*, written for the Tariff Commission by Carl R. De Long, chief of the Chemical Division, presented a broad picture in sharp focus.\* It had been definitely settled, for example, that because synthetic methanol does not contain the aldehydes, ketones, allyl alcohol, and various acids found in the product of wood distillation,<sup>13</sup> which give it its distinctive taste and smell, the pure product is less suitable as a denaturing agent. Recognizing this, and prompted to aid an American industry, the Treasury Department specified crude methyl alcohol in both completely and specially denatured formulas. Thus a ruling created an outlet for about a third of the output of the American industry.<sup>14</sup> This exclusive market, which promised to grow, and its joint products, acetate of lime, tar, and especially charcoal, gave the wood chemical industry a fighting chance of survival.

Acetone, a by-product of butyl alcohol fermentation and from chemical synthesis, as well as synthetic acetic acid, were admittedly threatening competitors. Nevertheless, such experienced wood distillation men as Martin F. Quinn,† veteran operator of nine plants in Pennsylvania and two in New York; W. L. Saunders, who for many years had been associated with D. F. Diggins in the Cadillac Chemical Company;‡

\* "Personally, I think this case is a good example of the futility of trying to use tariffs to meet competition from inevitable scientific progress. I argued this with the Tariff Commission before the investigation was made on the basis that this was a really new development and in a short time it would be established in the U. S., so any increase in duty would be of temporary benefit to the wood chemical industry. However, the politicians insisted on making the investigation and I had to do the best job I could." (C. R. De Long, to author, June 4, 1946.)

† At the time of his death, Mar. 30, 1929, "Matt" Quinn was the last of the old-time wood distillation men, his brother, Thomas, with whom he started business in 1881, having retired in 1909. He headed the Vandalia Chemical Co. and the Keystone Wood Chemical & Lumber Corp., largest wood distillation operation in the world, and held directorships in 21 firms. He was born Apr. 1, 1854, in Olean, N. Y., where his plants were located for many years, and early in his career perfected the retort process so generally used in the destructive distillation of wood.

‡ Later, when agriculture invaded the Lower Peninsula of Michigan, raising land

William J. Merwin of Thomas Keery Company; W. R. Melville of Miner-Edgar Company; and Sydney H. Stilling \* of the Wood Products Company of Buffalo, all agreed that the obituary of the industry was premature. But they were unanimous in their conviction that it could survive only if it made the most of the economic advantage of its waste raw material and conducted its operations in wisely chosen locations, closely integrated with lumbering and sawmill enterprises.<sup>15</sup>

The Tariff Commission *Report* summarized the setup of the wood distillation industry as falling into three distinct districts: Eastern, Western, and Southern. The oldest section in the East comprised 50 active plants, centered around Olean and Hancock, New York, and Bradford, Pennsylvania. In the Western district were seventeen plants, fourteen in Michigan and three in northeastern Wisconsin. The Southern area, which was opened up during the war by the large, government-built plants,† had at this time three plants in both West Virginia and Tennessee and one each in Kentucky and Mississippi. These were large-scale, modern operations, and the district was obviously becoming increasingly important. Practically all the crude methanol produced, the *Report* pointed out, was shipped to nine refineries. Five of these, one of which was dismantled after synthetic competition appeared, were operated in conjunction with wood distilling plants and four independently. Of the four separately operated, two were owned by companies which also operated wood plants and two were independently owned. The sole refinery in the South, Tennessee Eastman, sold none of its output which was entirely self-consumed. The *Report* emphasized the fact that, except for charcoal, all salable products of the wood industry were meeting synthetic competition. Furthermore, synthetic acetic acid, which then came chiefly from the Canadian plant at Shawinigan Falls, Quebec, would no doubt soon be made in the United States.

Since the I.G. flatly refused to divulge any figures, the cost-finding investigation of the Commission was one-sided. But by taking the average delivered price of synthetic methanol in New York over the past eighteen months, which was 48 cents a gallon, and comparing it with detailed cost figures obtained from 57 different American operations, the conclusion was reached that the over-all delivered cost of the German material was 36 cents and of the American, 58 cents.

These figures were sharply questioned by Kuttroff, Pickhardt & Com-

values prohibitively, Saunders and his son, Clyde, migrated to Sault Ste. Marie, establishing there a large sawmill-chemical plant, the Cadillac-Soo Lumber Co., which operated successfully until a destructive fire in 1932.

\* In 1923, when Edward B. Stevens, founder of Wood Products Co., retired to chairman, Stilling, who had been with the co. since 1907, was elected pres. of the co., the outstanding refiners of crude methanol in the country.

† See Vol. III, p. 136.

pany, American agents of Badische, who filed the only brief in rebuttal. It was quite impossible, the importers claimed, to compare production costs of a single synthetic product with those of a chemical operation producing a number of related products and by-products. The accuracy of the comparative yields was also questioned, and it was claimed that the *Report* was based on data covering previous periods which did not reflect conditions existing at the time.<sup>16</sup>

The Commission's final decision was delayed by summer vacations, but the recommendation was unanimously for an increase in the tariff to 18 cents. President Coolidge proclaimed this rate effective as of November 29, 1926.<sup>17</sup> Almost immediately the price of acetate of lime advanced 25 cents to \$3.50 a hundredweight and a week later the price of denaturing methanol moved up 5 cents to 80 cents a gallon. Though these higher prices were certainly justified, they followed the 6 cents rise in tariff so quickly and so closely that they reawakened the old antagonism between the consumers and producers of wood chemicals.<sup>18</sup>

Historically, this group of chemicals had been infamous for wide fluctuations, and during the war, when the demand for acetone for cordite manufacture far exceeded the capacity of the distillation plants, quotations soared skyward. Such violent variations in price are economically inherent in a related group of chemicals produced from by-product materials in many small, decentralized plants. They evidenced a basic instability that had always dogged the wood distillers. Nevertheless, wood chemical producers and refiners had always quickly run prices up as high as possible on the flimsiest excuse.\* But in 1926 these high prices were short-lived. By May, the wood distillers were forced to lower the quotations on pure methanol (95-97 per cent grade) by 17 cents a gallon. The price of the denaturing grades remained unchanged, and chemical trade witnessed the almost unique price situation of a crude material selling for 12 cents a gallon higher than its refined product.<sup>19</sup> Refined methanol had to meet the price announced by new, domestic manufacturers of the synthetic, who were quoting 68 cents a gallon in tankcars to meet the German price of 68 cents in drums laid down in New York.

Repeated rumors of an American production of synthetic methanol had disturbed the wood distillers for some time. Trade gossip associated with such a project the names of a number of large chemical companies: du Pont, "U.S.I.," Union Carbide, Commercial Solvents, Mathieson Alkali, and even such strong outsiders as General Motors and Standard

\* "The practice persists. The modern notion of greater volume, lower cost, improved quality, and a gentler regard for the buyer has not been generally adopted by the wood distiller from his more successful synthetic cousin." (Douglas S. Calder, to author, July 23, 1946.)

Oil. Badische denied time and again that it sold the American rights to its patent "to du Pont or anyone else."<sup>20</sup> In 1926, shortly before the higher tariff duties were proclaimed, the much discussed American synthetic production became a fact. Almost simultaneously du Pont and Commercial Solvents brought their new methanol plants on line.

The two ventures differed both in origin and operation. The du Pont process, the result of two years' concentrated work by the company's research and engineering staffs, dovetailed with its production of synthetic ammonia at Belle, West Virginia. In the purification of the hydrogen-nitrogen mixture for ammonia synthesis, carbon monoxide was removed and by passage over a catalyst combined with the hydrogen to form methanol.\* This was removed by condensation along with such impurities as water, methane, and sulfur, under a pressure which promoted the subsequent ammonia synthesis reactions. Hydrogen, as such, was not provided for the methanol synthesis, which was accomplished while the gases were being purified on their way to the ammonia reaction chambers, thus achieving in a single operation the economic synthesis of two chemicals.<sup>21</sup> This process was abandoned within a couple of years, replaced by one in which methanol was synthesized from water gas.

The Commercial Solvents' operation, on the other hand, grew out of the utilization of by-product hydrogen and carbon dioxide formed during fermentation of corn to produce butanol. An obvious solution of this waste problem was the synthesis of ammonia, and after semi-plant equipment had demonstrated that it was commercially feasible to produce pure  $H_2$  from the fermentation gases, the Nitrogen Engineering Corporation of New York was commissioned to design and install at Peoria, a plant with a daily capacity of 12 tons of anhydrous ammonia. But ammonia synthesis left unaccounted for large volumes of waste carbon dioxide. At least a quarter of this would be consumed in methanol synthesis.† Accordingly, while the ammonia plant was building, the Research Department went to work testing all possible catalysts under a wide range of pressures to evolve a practical methanol synthesis adapted to their peculiar requirements.

A contest developed whether the ammonia plant or the methanol process would be finished first, a race that ended virtually in a dead heat. The alcohol synthesis was advanced from the laboratory to a 50-gallon-a-day pilot plant. The ammonia equipment was run for 30 days and

\* When du Pont acquired Roessler & Hasslacher in 1930, it got the Storch patents (U. S. 1,681,750-3), granted Aug. 21, 1928, on copper catalysts for the conversion of CO and  $H_2O$  to methanol.

† The reaction is  $3H_2 + CO_2 = CH_3OH + H_2O$ . As the H volume ran 40-42%, production of methanol utilized only about 25% of the  $CO_2$ . (Chas. L. Gabriel, to author, June 3, 1946.).

proved out at almost twice the 12-ton-a-day rated capacity. This was an imposing demonstration of plant efficiency. Nevertheless commercial considerations favored methanol. The double salvage of hydrogen and carbon dioxide was a weighty argument. More than this, the ammonia market at the time was oversold with du Pont's Belle plant in production and the larger Allied plant at Hopewell under construction. The demand for methanol, on the contrary, was still growing and there was every prospect that the increased tariff would prevent the Germans from monopolizing the market. The ammonia apparatus was therefore readjusted; the catalyst changed; and the new plant began turning out methanol on a commercial scale, on May 11, 1927. By autumn, daily production amounted to 4,500 gallons of pure methanol.<sup>22</sup>

The process at Peoria was very simple: The waste gases were scrubbed under pressure to remove part of the carbon dioxide, further compressed to about 4,500 pounds, then run over the catalyst at an elevated temperature. Distillation of the methyl alcohol-water mixture yielded a practically 100 per cent methanol. Availability of waste gases made this operation exceedingly economical and the installation at Peoria was doubled.\* The du Pont Ammonia Corporation also promptly expanded its methanol production and late in 1929 announced plans to treble the output at Belle, where the capacity was 2,000,000 gallons of this and other alcohols a year.<sup>23</sup>

In spite of the appearance of American synthetic methanol and of the higher duty, during December 1926 and January 1927, the first two months after the 50 per cent rise in tariff, German imports reached 312,196 gallons, the largest on record. During 1927, however, American synthetic production got into full swing. It was confidently forecast that it would shortly drive the German material off the market, and that the position of the wood distillers was more precarious than ever.<sup>24</sup>

But the wood distillers refused to admit defeat. In fact, they displayed a great burst of activity which was by no means their death throes. These activities were both commercial and technical.

From the economic point of view, the most significant development was the continued concentration of production into fewer and larger plants. Census figures reveal that between 1923 and 1929 the number of hardwood distillation establishments dropped from 76 to 53, while the average size of these plants, measured in daily capacity of cordwood, rose from 51.8 to 59.8, although the annual consumption of wood had fallen over 200,000 cords.†

\* The by-product gas capacity at Peoria was 4,200,000 cu. ft., at Terre Haute, 1,950,000, with H<sub>2</sub> amounting to 1,680,000 and 780,000 cu. ft., resp. The weight of the CO<sub>2</sub> in this mixture was 6,900 tons per month, and even after methanol synthesis, the excess was enough to constitute a "white elephant" and be discarded. [See J. C. Woodruff, *Ind. Eng. Chem.* 19, 1147 (1927).]

† For production of wood chemicals, see Appendix XXXIII.



As an aftermath of the Government's war effort, the newly opened wood chemical territory in the South had acquired three large plants in strong hands.\* The economic setup was distinctive. At Kingsport, the Tennessee Eastman Corporation † operated the war-built plant which had been purchased from the American Wood Reduction Company in 1920 to supply the Kodak subsidiary with methanol, acetic acid, and ethyl acetate, raw materials for its final products, sensitized film and paper and cellulose acetate film base. Its chemical production, therefore, never reached the open market, and it was operated throughout essentially as a safeguard against the risky contingencies looming ahead in the entire methyl group of chemicals.<sup>25</sup>

The big Bon Air plant at Lyle, Tennessee, purchased in 1919 by the Tennessee Products Corporation of Nashville, was also an integrated operation but upon quite a different basis. The company owned and operated the Chattanooga Gas & Coke Company, the Rockdale ferro-phosphorus blast furnace, coal and iron mines, and extensive timber holdings. Much of the charcoal produced from the 220 cords of wood carbonized daily was self-consumed in the production of a high-grade pig iron, while the balance was marketed for domestic purposes throughout the South. The daily production of 2,000 to 2,500 gallons of methanol was all sold in the 90 per cent denaturing grade; the acetate of lime went to white lead and lacquer solvent manufacturers.<sup>26</sup>

Near Memphis the Forest Products Chemical Company, built during the war and operated afterwards by William Henry Matthews, an old hand at wood distillation, stood on its own feet without any affiliated consumption of its product. Like Tennessee Products, it marketed its charcoal in the domestic field and of necessity exploited its chemical possibilities to the utmost. It was, for example, the first American wood distillation plant to adopt the Suida process ‡ for direct recovery of acetic acid.<sup>27</sup>

To sidestep production of acetate of lime in this way was the first

\* See Vol. III, p. 137.

† Incorporated for \$3,500,000 in Va., the Lumber & Wood Dept. was from the first under the active management of James C. White, who was born in the Michigan wood chemical country, Aug. 29, 1889. At 21 he went into lumbering, first with his father, A. J. White, and later with the Hope Falls Logging Co. He served in France with the A.E.F., being cited for conspicuous bravery by Gen. Pershing and awarded the Purple Heart.

‡ Depends upon the solvent action of a heavy tar oil distillate upon acetic acid vapors. The still vapors are passed into the bottom of a scrubbing tower and the tar oil enters at the top, absorbing the acetic acid, and condensing some water, while the methanol and acetone, the other constituents of the crude pyroligneous vapors, and the remaining water escape from the top. The acetic acid-water-tar oil mixture is separated by successive passage through scrubbing and stripping columns and by final rectification. [See Brit. Pats. 218,271-2 (1927); U. S. Pats. 1,621,441 and 1,624,810-12 (1927).]

technical answer to the threats of synthetic methanol and acetic acid. The Suida process, which was installed at Memphis in 1928 under the able supervision of T. C. Albin \* and later at the Crossett Lumber Company plant in Arkansas, was the best method of direct recovery of acetic acid at the time, but it was replaced in the late thirties by the ethyl acetate extraction process.<sup>28</sup>

Two years before the German synthetic invasion, another large wood chemical plant, operating upon the closely integrated use of waste raw materials and self-consumed finished products, and employing another novel process, was established in Michigan. It was adjunct to the wood-working plant of the Ford Motor Company.<sup>29</sup> In many ways this was a decided innovation. Its chief source of raw material was not lumbering waste, but the scrap from the body plant; chips, shavings, and even sawdust, all quite unsuitable for carbonization in the regulation iron buggies. By necessity, some process capable of employing this finely divided material had to be adopted and the Stafford process † was installed.<sup>30</sup> The waste from the company's lumbering operation, reduced to chips in a hogging machine, was mixed with the wood-working plant's scrap; dried and preheated by the waste flue gases from the power plant; fed into a vertical retort where the exothermic reaction raised the temperature of the fresh, incoming scrap to the reaction point. The rapid heat exchange between the incoming dry material and the hot vapors eliminated the necessity for stirring or agitating the charge and once the retort was in operation, no further application of heat was needed from the outside.<sup>31</sup>

Employing both lumbering and wood-working wastes, this Iron Mountain operation supplied ethyl acetate for the Ford finishing plant. The production of this solvent by direct esterification of the weak pyroligneous acid was the most novel feature of this unique wood chemical plant.<sup>32</sup> Charcoal, which of necessity had to be briquetted, was sold, bagged and branded, through retail channels. This plant, which went on line, August 1924, was a model, not only of chemical engineering skill, but of exacting "housekeeping" for which all Ford plants are famous.

The Ford and Eastman plants were something quite new in the wood chemical industry: operations by firms that had no forest background.‡

\* An important man in the modernization of the wood chemical industry, for he designed the Suida process plants of both Forest Products and Crossett, and in 1939 revamped W. H. Matthews' Newberry operation for the newer ethyl acetate recovery system. He was one of the first advocates of the still later Reichert process. A very resourceful and forward-looking engineer, Albin's modesty has kept him out of the limelight, and he has never had the recognition his outstanding work deserves. (M. H. Haertel, to author, June 9, 1946.)

† U. S. Pat. 1,380,262 (1921).

‡ Again I am indebted to Dr. M. H. Haertel for placing at my disposal his manuscript notes on the historical development of the wood chemical industry. (W. H.)

The fresh point of view—highly mechanical and exceedingly cost-conscious among the Ford management and essentially chemical on the part of Eastman—was exhilarating to the entire industry. Their famous names, their ample resources, the scale of their operations, their thoroughly modern approach to the old technique of wood distillation, and above all, their confidence, despite synthetic competitors, furnished both encouragement and inspiration. Their practice preached the gospel of new methods—chemical control and mechanization—and proved the dollars-and-cents worth of preheating wood and the direct recovery of acetic acid.

The example of these operations also strengthened the tendency toward fewer and larger plants. They discounted the loss of the charcoal-iron business and the fear of new rivals, so that bolder spirits among the wood chemical men were prompted to follow the trail they blazed. Concentration was most evident in the older, Eastern area. Here a number of small units, which prior to 1905 had pulled down the average to 24 cords, entirely disappeared during the twenties.<sup>33</sup> In the new Southern territory, the three big plants which survived the postwar liquidation—Tennessee Eastman, Tennessee Products, and Forest Products—had a combined capacity of 380 cords daily, but 600 cords of war-built capacity had vanished. Nationally considered, these Southern plants were at once a net gain in domestic production and a marked gain in average capacity.

By 1930 only a handful of plants were operating on less than 40 cords a day. The growth of the average unit was due partly to these new, big plants and partly to consolidations. Conspicuous among these was the Keystone Wood Chemical & Lumber Corporation, into which M. F. Quinn consolidated his numerous small plants in a single operation at Glenfield, New York. This amalgamation, which began in 1925 and was signalized by the installation of a larger, improved type of vertical retort, culminated in 1927 in the organization of this corporation, with 15,000 preferred shares of \$100 each and 15,000 shares of no-par common.<sup>34</sup>

The Cadillac-Soo Lumber Company of W. L. Saunders and his son Clyde, in the northern section of Michigan, was another example of this tendency. Closely integrated with lumbering operations, the initial plant, designed for 100 cords daily, was soon expanded to 112 cords to strike a proper balance with the sawmill activities.<sup>35</sup> Akin to this, in that it was built upon a lumbering foundation, was the Arkansas plant of the Crossett Chemical Company. Frankly a waste-salvaging proposition, this enterprise, the first operating wood chemical plant west of the

Mississippi,\* was conceived upon a large scale with a broad, economic outlook and an appreciation of chemical technology which led it to install the Suida process.<sup>36</sup>

Out on the West Coast, in 1927, a unique wood distillation plant began operations upon an entirely unorthodox pattern at Stege, California. The Western Industries Company of San Francisco built a \$250,000 operation to carbonize peach and apricot pits for the production of high-grade, decolorizing carbon.<sup>37</sup> This plant was designed for a French process to make ethyl and methyl acetates by direct mixture and joint distillation of pyroligneous acid and alcohol. The operation was successful, but was closed down because after it came into production in 1929 the prices of its products and by-products dropped to half what they had been when the plans were made. This enterprise led later to the formation of the Lacquer Chemicals, Inc., a joint subsidiary of Western Industries and Stauffer Chemical Company, which made nitrocellulose for the coatings industry.

During the 1920's the explosive changes within the industry and the outside pressure of synthetic competition closed more than 30 small, independent wood chemical plants.<sup>38</sup> Two-thirds of these were in New York and Pennsylvania, the others in Michigan and Wisconsin. In 1927 one of the larger wood distillers, the Miner-Edgar Company of New York, went into a receivership.† The company, which was associated with the Publicker Commercial Alcohol Company and the Sutton Chemical Company, did a gross business of over \$6,000,000, and operated plants in New York, New Jersey, Pennsylvania, and West Virginia.<sup>39</sup>

Pressure of German competition cracked wide open the weak, disorganized sales system of this decentralized, small-unit industry, and to meet it, a united front in sales was organized in two different directions. The Wood Distillers Corporation of Olean, New York, was organized in 1928 and made a contract with Thomas Keery Company of Hancock, New York, to take crude methanol from the affiliated companies, refine it, and market the finished product.<sup>40</sup> W. Z. Georgia was president, W. L. Heim, vice-president, and I. H. Burns, secretary, treasurer,

\* During World War I a large wood charcoal plant was built by the Government at Midco, Mo., but it never produced and was salvaged at almost a total loss. (See Vol. III, p. 136.)

† Creditors were Kentucky Alcohol Corp., Orelite Co., R. C. Rathbone & Son, U. S. Industrial Alcohol Co., N. Y. Dock Co., and Goldsmith Bros. Dir. were Henry H. Miner, Harold T. and D. Raymond Edgar, Philip Publicker, and William R. Melville. Miner-Edgar acted as sales agents for Edgar Bros. Co., miners and refiners of clays. This company was separate and solvent at all times and continued with D. Raymond Edgar as pres., until his death, when he was succeeded by his brother, Harold.

and general manager.\* A month later, William S. Gray & Company of New York took over the sales for the group.<sup>41</sup> But this ambitious effort to unify production fell apart within a couple of years, partly because of divergent interests, but chiefly because of the group's inability to secure sufficient refining capacity to take care of the production of its members. In the sale of charcoal, a similar, longer-lived movement was no more successful. In 1926 the Western Charcoal Company of Chicago became sales agents for the Thomas Berry Chemical Company, Manistique, Michigan; Charles T. Clark, Bay City, Michigan; Cliffs Chemical Company, Goodman, Wisconsin; Hackley-Phelps-Bonnell Company, Phelps, Wisconsin; Forest Products Chemical Company, Memphis, Tennessee; and the Cummer & Diggins Company of Cadillac, Michigan.<sup>42</sup>

As if the upset in methanol were not enough, these crowded years saw a parallel disturbance of acetic acid processes and markets. The chemical uses of this acid † increased by leaps and bounds due, chiefly, to the growing production of cellulose acetate film and filaments and the new employment of organic acetates as solvents.<sup>43</sup> Coinciding with this came the first imports of synthetic acetic acid, a combination which made obsolete the old method of distilling acetate of lime with sulfuric acid to produce acetic acid. The already hard-pressed wood distillers were forced to adopt direct methods of producing the free acid.

Synthetic acetic acid from calcium carbide was a Canadian chemical triumph, an outgrowth of the war-born effort to synthesize acetone as a cordite solvent at the plant of the Canadian Electro Products Company, subsidiary of the Shawinigan power interests.‡ By 1925 the output reached 12,000 tons a year and although most of this was exported to Great Britain, nevertheless its American selling subsidiary, the Shawinigan Products Corporation, managed by Louis F. Loutrel,§ began making offers in this country of sizable quantities at attractive prices.<sup>44</sup> The two-cent-a-pound import duty naturally suggested that the growing American demands be met by production in the United States. Accordingly, in 1925 Shawinigan manufacturing know-how, Union

\* Besides Georgia and Heim, the dir., who represented all affiliated producing co's., were G. S. Barclay, F. P. Bell, M. C. Burt, F. F. Clawson, T. F. Connelly, J. A. McCormack, M. F. Quinn, M. M. Quinn, John Troy, A. J. Keery, W. J. Merwin, G. H. Treyz, and G. I. Treyz.

† Total domestic consumption of 28% acid was estimated at 78,500 short tons in 1927. Of this 96.4% went into chemical processes, the most important being rayon and textiles, 28,500 tons; fine chemicals, 24,000; paints and varnish, 10,000. [See *Chem. Met. Eng.* 34, 586 (1927).]

‡ See Vol. III, p. 152; Haynes, *Chemical Front*, p. 33.

§ For more than 20 yrs. "Lou" Loutrel has filled the exacting post of U. S. representative of the Shawinigan power interests in the chemical field, being pres. and gen. mgr. of Shawinigan Products Corp., and serving on the bd. dir. of Fiberloid. He was born on June 15, 1890, and educated at Yale-Sheffield.



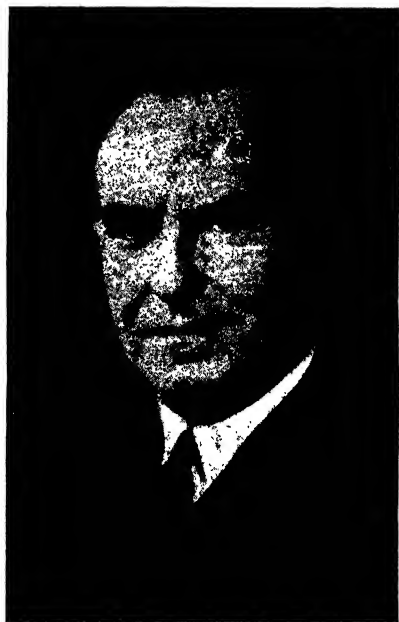
G. B. LANDES



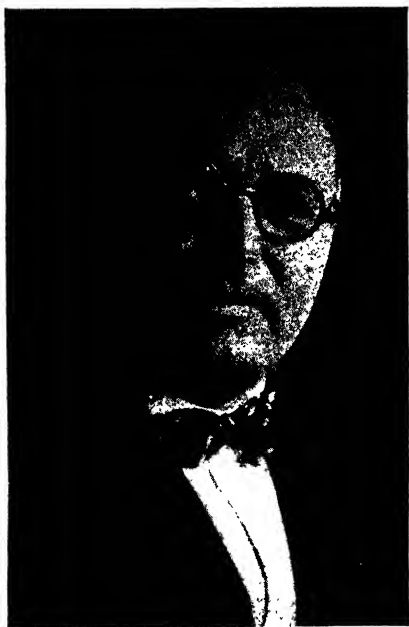
GEORGE O. CURME, JR.



H. EARLE THOMPSON



JAMES A. RAFFERTY



*Chemical & Metallurgical Engineering*

**MICHAEL J. CALLAHAN**



**PHILIP T. SHARPLES**



*Oil, Paint & Drug Reporter*

**CHARLES L. GABRIEL**



*Oil, Paint & Drug Reporter*

**THEODORE P. WALKER**

Carbide's calcium carbide and acetylene, and Roessler & Hasslacher's consumption of acetic acid, resulted in the joint enterprise, the Niacet Chemicals Corporation, formed with a capitalization of \$1,500,000 preferred stock and 75,000 shares of no-par common.<sup>45</sup> The associated companies were represented on the board by William F. Barrett, Benjamin O'Shea, and James A. Rafferty of Union Carbide; Julian C. Smith, R. A. Witherspoon, and H. S. Reid of Canadian Electro Products; and Philip Schleussner, Colby Dill, and P. Samuel Rigney of Roessler & Hasslacher. Barrett was president, Smith vice-president, Schleussner treasurer, and Rafferty secretary.

A plant was built at Niagara Falls, New York, and put in charge of Waldo C. Hovey.\* The products were acetaldehyde, paraldehyde, acetaldol, and crotonaldehyde. The brisk demand for rubber accelerators and antioxidants created a good market for these various aldehydes, and while the life of any rubber accelerator was short, nevertheless the profits were good. The plant called for synthetic production of acetic acid at the opportune time and this was executed during the summer of 1928. Before acetic acid was ready for the market, Niacet sales were taken from Roessler & Hasslacher and its own sales organization was formed under Clarence J. Herrly.†

Two processes for direct recovery of acetic acid from crude pyro-ligneous liquors were the answer to these synthetic developments. The Brewster process was developed in England in 1923 by Dr. Theodore J. Brewster. He died in 1925 just after American rights to his patent had been bought by H. J. Baker & Bro. and J. P. Carter, who was associated with Chemical Solvents, Inc. Brewster's method depends upon extraction by isopropyl ether. Its first American test was at the Keystone Wood Products Company in the spring of 1925. It was reported that a trial run on 940 cords of wood showed a \$1.56 per hundredweight conversion cost to 100 per cent acid.<sup>46</sup> Eighteen months later Keystone was offering acetic acid at a price so low that it indicated other makers would have to obtain acetate of lime at \$2.50 per hundred pounds, instead of the current \$3.25.<sup>47</sup> A dispute arose over the terms of the patent rights and the Federal Court of the Western District of Pennsylvania awarded a verdict of \$87,000 to the Baker firm and Carter.<sup>48</sup> A year later the Brewster process was thrown wide open

\* A Canadian, born at North Hatley, Que., Mar. 4, 1894, and educated at McGill (B.S., 1916), Hovey was a veteran of the experimental work at Shawinigan Falls that established this process and when moved to Niacet was supt. of the Canadian Electro Products plant. He left Niacet in 1944 to take charge of production for Wyeth in Phila. and in 1946 became vice-pres. of the Harshaw Chemical Co., Cleveland.

† Since 1917 Herrly was in the thick of the development of chemical processes, starting with acetylene at Union Carbide. He was born in Pittsburgh, Jan. 29, 1893, and earned his Ph.C. at Medico Chirurg. Coll. and B.S. at Pa. State.



when the patent application was rejected on the grounds that the method of solvent extraction had been invented by a German named Goering in 1884, but never used.<sup>40</sup>

In the meantime the Suida process had been installed at the Forest Products Chemical Company. The process, as adapted at the big Memphis plant, displayed certain modifications of original European practice perfected by Professor Suida of Vienna. These were accomplished after years of experimental work by Forest Products chemical engineers led by T. C. Albin.<sup>50</sup> Both these processes have persisted, the Brewster \* being particularly adaptable to the cellulose acetate plant, while the Suida process enjoys the advantages of continuous re-use of high-boiling tar oils.

Acetone was also profoundly disturbed during this period. During the war its dire need as a solvent made it the chief end of the butanol fermentation of corn. With the return of peace and the new demand for butyl alcohol and butyl acetate from the youthful lacquer industry, acetone became a by-product and the price fell.

England was the battleground of the fight between American surplus fermentation acetone, synthetic acetone from Canada, and natural acetone from the Continent.<sup>51</sup> With the removal of the 33 $\frac{1}{3}$  per cent duty levied under the Key Industry Act, synthetic material took control of the market. Its production increased in Canada and two new synthetic processes were announced, the one in Germany † from alcohol by treatment with steam in the presence of catalysts,<sup>52</sup> and the other in this country from propylene obtained from natural gas.<sup>53</sup>

American supply continued to come chiefly from the secondary product of butyl alcohol fermentation, and at hearings on tariff readjustment,<sup>54</sup> the Synthetic Organic Chemical Manufacturers' Association filed a brief strongly advocating that the ad valorem tariff of 25 per cent on synthetic acetic acid be increased to 40 per cent to furnish protection during the dangerous period of research and development. It pointed out that adequate supplies of this solvent, essential to the development of cellulose acetate industry, could only be supplied by a primary production in straight chemical operations.

The acetyl ( $\text{CH}_3\text{CO}$ ) and methyl ( $\text{CH}_3$ ) radicals were rapidly assuming a new prominence in plastics via formaldehyde, in dyes, in solvents and plasticizers, in anti-freeze, and conspicuously in acetic anhydride for the manufacture of cellulose acetate, and in methyl chloride as a refrigerant. Within a very few years requirements for their base materials, methanol, acetic acid, and acetone, far outstripped the capacity

\* Brewster, Brit. Pat. 187,603 (1922), later modified by Carbide & Carbon Chemicals Corp., U. S. Pat. 1,995,965 (1935). For comparative merits, see Riegel, *Industrial Chemistry*, 2d ed., p. 258; and E. P. Duchemin letter in *Chem. Mkts.* 19, 1401 (1926).

† K. Róka, Ger. Pat. 475,428 (1924), ass. to Holzverkohlungs Industrie A.-G.

of the wood chemical industry. Had it not been for the synthetic processes, this whole development would have been dwarfed. The same technological progress that ruined the small wood distiller, enormously widened the chemical horizon. As early as 1920 it had brought Kodak into the manufacture of these chemicals and in 1925 another consumer, the American Cellulose & Chemical Manufacturing Company, Ltd.,\* invaded the chemical market, offering acetic anhydride of higher quality and lower price than had been previously available.<sup>55</sup>

Amid these kaleidoscopic changes the wood chemical industry survived. By creating a wholly artificial market for natural methanol, Prohibition undoubtedly made this possible. But it would have been impossible if amid the cyclone of technological progress that swept away many smaller operators, a few courageous leaders, old and new, had not braved the storm and in its teeth rebuilt their operations from the ground up. This meant not only the adoption of new processes and the opening up of new outlets, but the adoption of a fresh, a strictly chemical, point of view.

Symbolic of this inward change was the metamorphosis of the National Wood Chemical Association of which M. H. Haertel † had been secretary since 1916,<sup>56</sup> into the Wood Chemical Institute, Inc., organized March 21, 1929, in Buffalo.<sup>57</sup> The directors were M. C. Burt, Gray Chemical Company; F. F. Clawson, Clawson Chemical Company; W. Z. Georgia, Buckhannon Chemical Company; W. L. Heim, Otto Chemical Company; A. J. Keery, Custer City Chemical Company; L. T. Kniskern, receiver of the Charcoal Iron Company; J. A. McCormack, Union Charcoal & Chemical Company; W. J. Merwin, Thomas Keery Company; M. F. Quinn, Vandalia Chemical Company; C. A. Saunders, Cadillac-Soo Lumber Company; John Troy, Heinemann Chemical Company. Heim was president, Merwin vice-president, and Kniskern secretary-treasurer. The purposes of the old association had been frankly commercial: chief objectives of the new were education and research. It entered into the hunt for better denaturants and during Prohibition days Doctor Haertel rendered a valuable, painstaking service by running down the true facts behind every newspaper account of methanol poisoning. The Institute turned to the cultivation of new

\* Succeeded by the Celanese Corp. of America, which during World War II carried this chemical production to a new level in the plant at Bishop, Tex., synthesizing these products from the oxidation of natural gas hydrocarbon fractions. (See Haynes, *Southern Horizons*, p. 263.)

† Prof. of economics at Wis. (1906-20) with 5 yrs.' business experience with Miner-Edgar Co., Haertel became a valuable trade assoc. executive. He was born in St. Charles, Mo., where he received his B.S. (1894) and did postgraduate work at U. Chicago (Ph.B., 1901) and U. Wis. (Ph.D., 1906). In 1926 he went to Wash. as representative of the Nat. Wood Chemical Assoc. and was reappointed to this post in 1929 by the Wood Chemical Inst.

uses for the products of hardwood distillation, notably in the domestic market for charcoal and charcoal briquettes, carrying on an effective educational campaign for their use in outdoor fireplaces in public parks and trailer camps.

## REFERENCES

1. *Drug Chem. Mkts.* 17, 11 (1925).
2. *Chem. Mkts.* 19, 1249 (1926).
3. *Drug Chem. Mkts.* 17, 623 (1925).
4. E. W. White, *Chem. Ind.* 54, 218 (1944).
5. *O.P.D. Repr.* 20 (Apr. 6, 1925); *Wall St. J.*, quoted in *Drug Chem. Mkts.* 17, 625 (1925).
6. *Chem. Met. Eng.* 30, 881 (1924); *Drug Chem. Mkts.* 15, 485 (1925), 16, 715 (1925); *O.P.D. Repr.* 71 (Apr. 14, 1924).
7. *Drug Chem. Mkts.* 17, 11 (1925).
8. *Ibid.* 16, 869 (1925).
9. For good contemporary accounts, see D. H. Killeffer, *Ind. Eng. Chem., News Ed.* 3 (June 20, 1925); *Chem. Mkts.* 19, 603 (1926).
10. *Drug Chem. Mkts.* 16, 1403 (1925).
11. *Ibid.* 1479; *O.P.D. Repr.* 21 (May 18, 1925).
12. Tariff Comm., *Report on Methanol*, 1927.
13. Klar, *Technology of Wood Distillation*, p. 244; Haynes, *Chemical Economics*, p. 37.
14. *Ind. Eng. Chem.* 19, 549 (1927).
15. *Chem. Mkts.* 19, 269 (1926).
16. *Ibid.* 493.
17. Tariff Comm., *op. cit.*
18. *Chem. Mkts.* 19, 1277 (1926).
19. *Ibid.* 20, 854 (1927).
20. *Drug Chem. Mkts.* 16, 1113 (1925).
21. *Ind. Eng. Chem.* 19, 547 (1927); *Chem. Met. Eng.* 34, 265 (1927); *O.P.D. Repr.* 21 (Mar. 28, 1927).
22. J. C. Woodruff, *Ind. Eng. Chem.* 19, 1147 (1927); C. L. Gabriel, *Ind. Eng. Chem.* 29, 1066 (1928); *Fortune* 170 (Dec. 1937).
23. *Chem. Mkts.* 25, 626 (1929).
24. *Ibid.* 21, 423 (1927); *Chem. Met. Eng.* 34, 196 (1927); B. R. Tunison, *ibid.* 35, 51 (1928); Tariff Comm., *Census of Dyes*, 1927, p. 132.
25. N. W. Krase, *Chem. Met. Eng.* 36, 396 (1929).
26. *Ibid.*
27. E. P. Partridge, *Ind. Eng. Chem.* 23, 484 (1931); E. P. Poste, *ibid.* 24, 722 (1932).
28. *Chem. Mkts.* 25, 179 (1929); D. S. Calder, to author, July 23, 1946.
29. *O.P.D. Repr.* 71 (Aug. 27, 1923); *Drug Chem. Mkts.* 12, 339 (1923).
30. Killeffer, *Ind. Eng. Chem.* 17, 999 (1925); Klar, *op. cit.* p. 470.
31. W. G. Nelson, *Ind. Eng. Chem.* 22, 312 (1930).
32. W. Haynes, *Chem. Ind.* 36, 15 (1935); Calder, *op. cit.*
33. M. H. Haertel, MS to author, Nov. 20, 1941.
34. *Ibid.*; *Chem. Mkts.* 20, 412 (1927).
35. Haertel, *op. cit.*
36. T. C. Albin, *Chem. Met. Eng.* 39, 382 (1932).
37. J. H. Dieckmann, Jr., to author, June 7, 1946; *Chem. Mkts.* 21, 338 (1927); *Chem. Met. Eng.* 34, 783 (1927).
38. Haertel, *op. cit.*
39. *Chem. Mkts.* 21, 786 (1927).
40. *Ibid.* 22, 305 (1928); W. J. Merwin, to author, June 5, 1946.
41. *Chem. Mkts.* 22, 421 (1928).
42. *Ibid.* 19, 663 (1926).
43. *Ibid.* 23, 257 (1928); *Chem. Met. Eng.* 33, 49 (1926).
44. *Drug Chem. Mkts.* 16, 1113, 1325 (1925).
45. *Ibid.* 2151.
46. *Ibid.* 1175; see also Partridge, *op. cit.*
47. *Drug Chem. Mkts.* 19, 852 (1926).
48. *Ibid.* 941.
49. *Chem. Mkts.* 21, 1 (1927).
50. *Ibid.* 22, 532 (1928); Krase, *op. cit.*
51. *Chem. Mkts.* 20, 648 (1927); 23, 284 (1928).
52. *O.P.D. Repr.* 62 (Nov. 4, 1929).
53. Tariff Comm., *Census of Dyes*, 1929, p. 135; *Chem. Mkts.* 24, 405 (1929).
54. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 8, 1929, p. 325.
55. *Drug Chem. Mkts.* 17, 1457 (1925).
56. *Chem. Mkts.* 19, 915 (1926).
57. *Ibid.* 24, 401 (1929); *O.P.D. Repr.* 62 (Apr. 1, 1929), 58 (May 20, 1929).

## Chapter 12

### SOLVENTS LEAD ORGANIC PROGRESS

FERMENTATION BUTANOL AND ACETATE COMPETE WITH SYNTHETIC BUTYL AND AMYL SOLVENTS FOR NEW LACQUER MARKET—AN ALIPHATIC INDUSTRY BASED ON PETROLEUM AND NATURAL GAS PIONEERED BY STANDARD OIL, CARBIDE AND CARBON: ISOPROPANOL, METHYL ETHYL KETONE, GLYCOLS, ETHANOLAMINES, CHLORINATED SOLVENTS—COMMERCIAL SOLVENTS MAKE ALCOHOLS FROM WASTE GASES—SHARPLES SOLVENTS CHLORINATES PENTANES—SOLVENTS INSTITUTE FORMED.

**A** PIONEER IN NITROCELLULOSE coatings, Michael J. Callahan,\* laid before the Institute of Chemistry in July 1927 a startling fact that kindled a warm debate. Addressing a picked group of some two hundred chemical educators gathered at Penn State College for a symposium on industrial developments, he said that more than 10,000,000 pounds of nitrocellulose lacquers were made and sold in the United States during the last half of 1926, as compared with less than 1,000,000 pounds during the whole of 1922.<sup>1</sup>

An old paint and varnish man, W. T. Pearce of Valentine & Company, declared at the same meeting that in contrast to the days of turpentine and wood alcohol, no single solvent could meet all the requirements of these new coatings.

Bruce K. Brown,† then with Commercial Solvents, rounded out the picture by this summary: "In the past four years a new lacquer industry has been created. The manufacture of lacquers has created an expanded solvent market and has stimulated research in the production of solvent materials. As a result, the number of organic solvents actually used in considerable quantities has probably been tripled since 1920."

That beautiful summer night, a group of chemical men sat on the veranda of one of the fraternity houses till the moon sank behind the

\* Save for 5 yrs. after graduation from Worcester Poly. (B.S., 1911), Callahan has been continuously with du Pont: research chem., 1916-20; asst. dir. Redpath Lab., 1920-22; chem. supt. Parlin plant, 1922-32; chem. dir. Fabrics & Finishes Dept., 1932-36; asst. gen. mgr., 1936-41; mgr. Fabrics Div., since 1941.

† Brown is an outstanding example of the too-rare chemically trained executive. With a B.S., Ch.E. (1918) and M.S. (1920) from U. Ill., he started as chem. engr. with the C. F. Burgess Labs.; was patent atty. for Commercial Solvents, 1924-28, and after a yr. with the law firm of Fish, Richardson & Neave, he became mgr. Patent & Development Dept. of Standard Oil (Ind.). He was promoted to the post of gen. mgr. of research and development in 1938. Asst. Deputy Admin., PAW during World War II, Brown since 1945 has been vice-pres. (development), Standard Oil (Ind.).

Nittany Mountains, discussing whether the new solvents or the new lacquers had come first; a debate as futile as the classic problem of the precedence of hen or egg. In retrospect, after twenty years, it is clear that the need of the lacquer industry for new, cheap, highly specialized solvents in great quantities inspired the most fruitful organic chemical researches of the twenties and garnered the richest harvest of new products.\*

Nitrocellulose coatings antedated the First World War and their merits were appreciated, but because the available solvents, crude amyl alcohol and amyl acetate, both from by-product sources, were limited, their uses were restricted to such fancy jobs as protecting gilded picture frames, metal lighting fixtures, and radiators. Urgent war needs for a coating to protect the cotton-fabric wings of airplanes reaffirmed the advantages of the tough, quick-drying lacquers and spurred some bold experiments in which quantities of acetone, ethyl acetate, amyl alcohol and acetate, and other solvents were used. After the war great piles of smokeless powder and guncotton sent Army representatives out to the important chemical companies, urging them to find some means of regenerating this surplus. Storage tanks brimming with by-product butanol † from the Weizmann fermentation process, operated during the war for its acetone, provided a ready-to-hand, inexpensive solvent. The problem of increasing the solid content having been solved by the low-viscosity nitrocellulose, and butanol and its acetate having proved suitable solvents, the new type of coatings became a large-scale industrial possibility. In 1922 the first motor car with a lacquer finish appeared.‡ Within two years the entire automotive industry had turned to this new finish.<sup>2</sup>

Almost overnight the business of Commercial Solvents Corporation was turned inside out, its wartime by-product becoming the principal product. While butanol made the early nitrocellulose lacquers commercially feasible, it also unwittingly and unwillingly encouraged a search for its own competitors. In 1921 a "poisoning" of the special strain of bacteria used in this fermentation seriously curtailed output in 1922 and 1923. Frantic search was made to learn the cause and find a cure. Bacteriological specialists were called in, but it was only after the company's own staff, under D. A. Legg, acting on the suggestion of Charles L. Gabriel,§ made mechanical changes that improved the

\* For production of the more important aliphatic solvents, see Appendix XXXIV.

† "There was one large tank at Terre Haute which was 100 ft. in diameter and held about 2,000,000 gal. This was later converted into a very nice swimming pool." (C. L. Gabriel, to author, June 19, 1946.)

‡ See Vol. III, p. 525.

§ A Mass. Inst. Tech. man (Ch.E., B.S., 1912; M.S., 1913) Gabriel was with Tide Water Oil, Baryta Mfg., and Port Morris Chemical Works, and 1st Lt., U. S. Army,

sterilization of equipment and prevented contaminated air from getting into the system, that the trouble was eliminated.\* The entire plant was scrupulously cleaned and started up again unit by unit with a newly cultivated, uncontaminated strain of fermenting bacteria. Later yields were increased by development of a more virus-resistant strain of bacteria.<sup>3</sup>

This production catastrophe happened most inopportunistically just when lacquers began to be applied to automobiles, creating a demand for butanol that Arthur Orr † estimated had grown in 1923 to 1,500,000 pounds a month.<sup>4</sup> Temporary lack of butanol and butyl acetate to supply the requirements encouraged the use of amyl alcohol and amyl acetate. Sales of the latter, according to the *Census of Dyes*, reached in 1923 the then-record of \$1,017,627 with a production of 3,207,022 pounds, not surpassed until 1928.<sup>5</sup>

The Commercial Solvents management decided that attack was the best defense. The 40 fermentators at Terre Haute were increased to 52 in hope of increasing production despite bacterial troubles.<sup>6</sup> The Majestic distillery at Peoria was purchased from the U. S. Food Products Corporation, remodeled,‡ and production of butanol and acetone started in December 1923.<sup>7</sup> About this time, too, the company announced that it had overcome the bacterial infection troubles.<sup>8</sup> These aggressive plans were being executed by a new vice-president, Theodore P. Walker.§

before joining Commercial Solvents as tech. salesman in 1920. He was promoted to sales mgr. in 1922, asst. to pres. in 1923, and vice-pres. in 1924-38. He left in 1942 to become vice-pres. of the Publicker Commercial Alcohol Co.

\* Similar difficulty was encountered during World War II in the U. S. Govt. fermentation plant built in Puerto Rico to supply butanol for the butadiene part of the synthetic rubber program. The trouble was identified by Prof. Elizabeth McCoy of U. Wis., assisted by Drs. J. C. McDaniel and J. C. Sylvester, as a series of four bacteriophages, and was eventually cured by cultivation of strains of fermenting organisms immune to this attack. (See *N. Y. Times*, May 6, 1944.)

† That yr. Orr had joined Commercial Solvents, having previously been in the foreign diplomatic service and banking. He became vice-pres. in charge of sales at Terre Haute, in 1927. He died in June 1933, two yrs. after resigning.

‡ To help Commercial Solvents in this crisis, in 1924 the Carbinol Products Co. was organized with a capital of \$2,500,000 by an impressive list of butanol consumers. Du Pont, Atlas Powder, Eastman Kodak, Egyptian Lacquer Mfg. Co., and Maas & Waldstein subscribed \$1,000,000 in preferred stock to help finance revamping the Peoria plant, the loan being paid out in butanol. Dir. were W. P. Allen of du Pont, Leonard Richards of Atlas, James H. Haste of Kodak, Paul Ruckgaber of Egyptian Lacquer, and Henry V. Walker of Maas & Waldstein. [See *Drug Chem. Mkts.* 14, 1019 (1924).]

§ "The Major," as Walker is known to his associates, earned this title in the Air Corps during World War I. He had previously been an officer in the Philippine Constabulary, resigning in 1916 to join Standard Oil (N. J.) in the Dutch East Indies, where from 1919-22, he was with the American Metal Co., Ltd. With Commercial Solvents since 1922, he was elected pres. in 1938, and also served as dir. of Thermoatomic Carbon Co., Commercial Molasses Co., and Corn Products Refining Co., and trustee of Drury Coll., where he graduated in 1908 and which awarded him hon. LL.D. in 1939. An aggressive

Hardly had these expansions been consummated, than synthetic butanol was offered for sale, and the January 1925 price established a new low, dropping from 26½ cents to 19½ cents.<sup>9</sup> During the next year, Commercial Solvents entrenched its position. The basic character of Weizmann's patent, as opposed to the Fernbach process,\* was established when the English High Court of Justice upheld Commercial Solvents' suit against the Synthetic Products Company, Ltd. Following this favorable decision, licenses to the process were sold in England and Italy, but as W. A. Burton, then vice-president, said at the time, the management was convinced the future of this process lay in America.<sup>10</sup> The company's financial structure was also tightened. The funded debt was eliminated by redeeming the outstanding five-year notes, June 1, 1926, and all stock was reduced to a single issue by converting preferred to B stock at 110 and either calling the A stock at 50 or converting it share for share into B. At the same meeting the directors voted \$1,000,000 for plant additions to manufacture butyl derivatives.<sup>11</sup>

Competition with synthetic butanol pointed plainly to the need for the most profitable possible employment of wastes and by-products and the importance of diversification. The waste gases, hydrogen and carbon dioxide, were used in the production of synthetic methanol.† Butanol capacity at Peoria was trebled,<sup>12</sup> so that during the first six months of 1927 output exceeded 26,000,000 pounds, more than two and a half times the production of but two years before.<sup>13</sup> Operations at both plants became specialized, Peoria concentrating on the large-scale production of butanol, acetone, ethyl alcohol, methanol, and their by-products, while Terre Haute, in addition to producing these primary fermentation products, went on and made their derivatives.

Up to this time U. S. Industrial Chemical and Van Schaack Brothers had acted as official converters of Commercial Solvents' butanol to butyl acetate, supplying this solvent to such large users as du Pont, Atlas Powder, Eastman Kodak, Egyptian Lacquer, and Maas & Waldstein. In this way "U.S.I." utilized the dilute acetic acid from the "vinegar process" which it had undertaken during World War I for conversion to acetone for the British Government, but it was obvious that the future of this promising lacquer solvent would depend largely upon its price and that it was logically a one-profit product. Accordingly, its preparation was started at Terre Haute in 1926. Butyraldehyde was also produced and it led to the preparation from it of dibutyl phthalate which soon became one of the most important of the new

leader, he inspired his company's excellent Research Dept. and its subsequent diversification into molasses and ethyl alcohol, carbon black and other pigments, vitamins from mash wastes, and nitroparaffins.

\* See Vol. III, p. 149.

† See Chap. 11.

plasticizers. Following the same line of diversification, acetone was converted to diacetone alcohol in expectation that it, too, would become an important solvent, but instead most of the output went into hydraulic brake fluids for automobiles.<sup>14</sup>

By the close of the period, Commercial Solvents' two plants had in operation 148 fermentators with corn-consuming capacity of 30,000 bushels daily, next to Corn Products Refining Company's production of starch, the largest industrial use of corn.<sup>15</sup> The practice of disposing of the "slops" from this vast quantity of fermented mash as cattle feed did not seem to be the most profitable solution of the waste-disposal problem. Attacked scientifically and from the chemical point of view, a better answer was found. Not only was the bran scalped from the corn and sold to feed manufacturers, but the kernels were degerminated, pressed to recover crude corn oil, and the oil cake ground into a high-protein poultry feed. Wastes were reduced and the value of the products increased by these methods, and this approach later led to further diversification in the recovery of riboflavin.

Butanol and butyl acetate attracted other companies. An allegedly novel fermentation process for the production of butanol and acetone prompted the organization, in 1929, of the Union Solvents Corporation, backed by Ohio and New York interests and capitalized for \$1,000,000.<sup>16</sup> Behind this new company, which acquired a plant from the Rossville Commercial Alcohol Company at Carthage, near Cincinnati, were B. E. Pollak and Jule P. Carter, who became chairman and president, respectively.\* The process was subsequently outlawed as an infringement of the Weizmann patents owned by Commercial Solvents.

The original lacquer solvents, amyl alcohol and amyl acetate, were not neglected. Imports of the crude material, especially from Russia, continued to increase during the period, which also witnessed the first synthesis via chlorination of pentane and subsequent hydrolysis with caustic soda.† This early and interesting use of petroleum hydrocarbons in organic synthesis was initiated at a casing-head gasoline plant in Texas, by Philip T. Sharples,‡ president of the Sharples Specialty Company of Philadelphia, manufacturers of centrifuges and other chemical equipment.<sup>17</sup> The separation of the pentanes from the wet-gasoline having been worked out and the chlorination process proved in a pilot

\* N. Frutkow was vice-pres.; J. C. Soelle, treas.; A. C. Sharpell, Jr., secy. The dir. were E. M. Allen of Mathieson Alkali; Chas. Bedaux, the efficiency expert; R. D. Clarke, the publisher; Arthur G. Hayes and Wm. S. Kies, N. Y. attorneys; E. Lasker; N. P. Rathoon; and T. Schulze.

† U. S. Pats. 1,691,424-6, ass. to Sharples Solvents Corp.

‡ Sharples was born at West Chester, Pa., and graduated from Swarthmore, A.B., 1910. He was with the White Heat Products Co. and later the Sharples Separator Co. till 1915, when he founded the Sharples Specialty Co. An early devotee of flying, he is a pioneer member of the Aviation and Pylon Clubs.



plant, the Sharples Solvents Corporation was incorporated in Delaware in 1926. A plant location was selected near Charleston, West Virginia, adjacent to the Belle Alkali Company, from which it was proposed to draw chlorine, the natural gas of the region providing ample supplies of pentane. After rectification of the crude product, the alcohol, containing seven of the eight possible isomers in normal and active or iso-amyl alcohol, was marketed under the trade name of Pentasol.<sup>18</sup> Commercial production began September 1926 and within the year the company was also producing amyl acetate sold as Pent-acetate. That same year the company exhibited at the Chemical Exposition samples of its recently developed amyl chloride.<sup>19</sup>

The West Virginia plant, which represented an investment of approximately \$1,750,000, had been constructed under the superintendence of C. Marshall Taylor,<sup>20</sup> but the management of the new company was soon placed in the hands of men trained in the Sharples Specialty organization, Lee H. Clark in the plant and N. J. Hooper in the sales office.\* In 1927 the corporation's capital was increased from \$500,000 to \$750,000 and that year Eastern sales were placed in the hands of C. P. Chemical Solvents, of which Rolland H. French, who had previously managed sales for Merrell, Wyeth, and Miner-Edgar, as active head.<sup>21</sup>

Like the other acetates, amyl acetate began to be increasingly used as a coatings solvent, and a number of firms in the industrial solvent and plasticizer fields began to produce it: American Solvents & Chemical Corporation, E. I. du Pont de Nemours & Company, Franco-American Chemical Works, Maas & Waldstein, the Miner-Edgar Company, U. S. Industrial Chemical Company, Van Schaack Brothers Chemical Works, the Whitbeck Chemical Corporation (which in 1927 changed its name to Industrial Solvents Corporation),<sup>22</sup> Publicker, Inc., and the Anderson Chemical Company, which sold out in 1927 to the Merrimac Chemical Company. The perfume and flavoring trades were served at this time by such producers as Felton Chemical, Florasynth, Fries & Fries, Morana, Northwestern Chemical, C. E. Ising Corporation, and van Ameringen-Haebler.<sup>23</sup>

Manufacturers of perfumeries, flavoring extracts, liniments, massage compounds, disinfecting fluids, and other preparations for external use also exerted considerable influence upon the early commercial development of another solvent derived from petroleum, isopropyl alcohol.<sup>24</sup>

\* Clark was at the time chief chem. of the Specialties Co. and became plant mgr. of Sharples Solvents in 1929. He has a B.S. from Cornell (1919) and before joining Sharples, was with the National Sugar Refining Co. and the General Chemical Co. Hooper, with a B.S. in eng. from U. Wis. (1917) was asst. supt. of the Cotton Oil Refining Corp. before becoming div. mgr. at Specialties in 1923. He transferred to the Solvents Corp. in 1927.

Since 1920 the Standard Oil Company of New Jersey had produced this alcohol on the basis of patents issued to Carleton Ellis and his associates.\* This synthesis was greatly furthered by the discovery of Matthew D. Mann, Jr., and Robert R. Williams,† that a mixture of mineral oil and sulfuric acid simplified the absorption and reaction of the propylene by the acid and reduced the polymerizing effect of the acid on the olefin. Working on refinery gases containing a mixture of olefins from which not only isopropyl, but also the secondary butyl, amyl, and hexyl alcohols may be derived, Standard Oil produced these compounds, and by employing the processes perfected by its Development Department, also manufactured isopropyl and secondary butyl acetates.<sup>25</sup> Isopropyl alcohol was also produced during 1925 and 1926 by the hydrogenation of acetone by the Newport Chemical Works.<sup>26</sup> The purity of the product was unexcelled, but the costs were high so that when Standard Oil entered the market actively with its isopropyl from petroleum and the price declined very rapidly from \$4.50 a gallon to about \$1.50 early in 1927, Newport was eliminated.

Another oil company, Cities Service, through its Doherty Research Corporation, also made isopropyl alcohol and formaldehyde on a modest commercial scale at the plant of the Empire refineries at Okmulgee, Oklahoma. A third petroleum company entered the field when the Barnsdall Corporation financed a three-year research project by the Arthur D. Little organization. This led, with the joint backing by National Distillers' Products Corporation and the banking house of Blair & Company, to the organization of the Petroleum Chemical Corporation,<sup>27</sup> which erected a plant at Tiverton, Rhode Island, in 1925-26. In addition to isopropanol, it was planned to produce the secondary butyl, amyl, and hexyl alcohols, but after operating six months, the unit was dismantled. Under direction of Dr. Benjamin T. Brooks, the Barnsdall Corporation continued experimental work along these lines in a small commercial plant at its Barnsdall, Oklahoma, refinery. In this connection, fractionating equipment for separating the light olefin fractions was installed at the refinery of the Pure Oil Company, Muskogee,

\* See Vol. III, p. 147.

† Dr. Williams was born in India in 1886, and educated at Ottawa U. (1903-5) and U. Chicago (B.S., 1907, hon. D.Sc., 1941). He was chief chem. of Philippine Bur. Science (1909-15) at the time another hydrocarbon alcohol pioneer, B. T. Brooks, was there. Before coming to Bell Telephone Labs. in 1925, as chem. dir., Dr. Williams was with the Bur. Chem., Melco Chemical, and Western Electric. During World War I he served in the Chem. Warfare Serv. and Bur. Aircraft Prod., and from 1925-35 was research assoc. at Columbia U. He has received many honors for his outstanding work in isolating vitamin B<sub>1</sub>, determining its constitution, and developing a method of synthesis, including the Gibbs medal (1935), Modern Pioneer award (1940), and Chandler medal (1942).

Mann was with Williams at Melco, from which he went to Southern Power, then Southern California Edison Co., and finally Standard Oil Development. He is a graduate of Yale (Ph.B., 1906) and Cornell (Ch.E., 1908) and holds many petroleum patents.

Oklahoma. Both operated until 1932, when the Petroleum Chemical Corporation was merged with the Standard Oil Company of New Jersey in the formation of the Standard Alcohol Company.

By 1927 all these higher aliphatic alcohols from unsaturated hydrocarbon gases were in commercial production, and most of the corresponding acetates had been prepared. Isobutyl alcohol had been synthesized in apparatus similar to that used for methanol from carbon monoxide and hydrogen, and refinements in the process of synthesizing methanol were worked out by A. T. Larson and W. E. Vail of the Ammonia Department of the du Pont Company so as to increase purposefully the yield of isobutanol.<sup>28</sup> Synthetic butanol was also an industrial reality, having been made at Union Carbide and Carbon Research Laboratories, Inc., in Long Island City, and installed at the Canadian Electro Products Company plant at Shawinigan Falls, Quebec.

This galaxy of new solvents was outshone as a singlehanded accomplishment by a series of aliphatic compounds developed and commercialized by the Carbide and Carbon Chemicals Corporation.<sup>29</sup> Work by George O. Curme, Jr., begun at Mellon Institute in 1914 and translated by his associates to plant-scale apparatus at the converted natural gas plant at Clendenin, West Virginia,\* had evolved workable processes for the synthesis of half a dozen chemicals with likely commercial futures. The time had come to capitalize these researches and a careful campaign for exploiting the most promising new products was plotted. That the Clendenin site was unsuitable for large-scale development was obvious. Its inaccessibility, a tremendous advantage during the experimental phase, would be a distinct geographic handicap. Adequate future supplies of power and water and of hydrocarbon gases, either from natural gas or cracked petroleum, loomed large, for these blueprints of the future mapped large markets for some of these chemicals and they must be "set right" on quantities and costs of raw materials. Boldly as they dreamed, they did not foresee the rapid expansion of the next ten years.

After many investigations Charleston, West Virginia, was the location selected. An attractive inducement was the half-closed plant of the Rollin Chemical Company. Here were eight acres of land, a waterfront on the Kanawha River with good shipping facilities, cheap power from the Virginian Power Company (now the Kanawha Valley Power Company), water from Rollin's own pumping station, and chlorine available from the near-by Warner-Klipstein cells. This Rollin plant had started as the pioneer barium chemical enterprise of the country. Its English owners, the Rollin brothers, had been cajoled by the prospect of quick and easy war profits into following the example of their neigh-

\* See Vol. III, p. 168.

bor, the Warner-Klipstein Chemical Company, and had installed electrolytic chlorine cells with supplementary apparatus for the production of carbon bisulfide, carbon tetrachloride, and monochlorobenzene. This excursion into a strange field overstrained the Rollin resources, and unfortunately the new plant was completed just too late to enjoy the war business. With marketless chlorine derivatives and the demand for barium products crippled by the depression, the Rollin enterprise had been forced to close down. Colonel J. J. Riley had undertaken the rehabilitation of the barium end of the business,\* reorganizing it as the Barium Reduction Corporation, and Carbide and Carbon Chemicals negotiated a favorable lease of the balance of the property, beginning November 30, 1923.

In the first formal plans for the new Carbide and Carbon plant, raw materials were to be obtained from the hydrocarbon concentrates of the South Penn Oil Company. Twenty-five million cubic feet of natural gas per day, treated in an activated carbon absorption plant, were to furnish the raw materials ethylene and propylene. Processing in the new stabilizer columns developed by Carbide would result in ethane, propane, and butane and the residue was to be sold to local gas companies. Pyrofax gas appeared as the first commercial product in 1921. Primarily propane, this "bottled" gas loomed quite as large as did any chemical. In fact, throughout the Clendenin experience, liquid petroleum gases were prominent commercially, furnishing much of the early income. Promptly after the plant's removal to South Charleston, however, with the growth of the chemical business these gases made excessive demands upon available raw materials. Separation of the enterprises was logical. Carbide and Carbon had led the way in "bottled gas" of standardized quality, having an excellent distribution system developed by its associates in Union Carbide, the Prest-O-Lite Company, and the Linde Air Products Company. In early 1929, a new liquefied petroleum gas plant was put in operation at Hastings, West Virginia.† The operation was in charge of Conrad M. Suter, one of the colorful, popular pioneers who was first with Linde and in 1920 worked on the helium project in Texas.

The chemicals slated to head the list for commercial exploitation at Charleston were isopropyl alcohol, then selling as a substitute for regulation-ridden ethyl alcohol, at the tidy price of \$5 a gallon, ethylene

\* See Chap. 9.

† Besides Pyrofax gas and natural gasoline, the Hastings plant produces butane, which is sold to replace small, uneconomic gas plants, to give household gas to new communities, and to enrich manufactured gas. Here cylinders are filled, but most of the output leaves in tankcars for filling stations all over the Eastern and Central states. Hastings provided Pyrofax gas for refueling the *Graf Zeppelin* at Tokyo and Los Angeles in her world-rounding flight of 1929.

glycol and acetone, the last to be delivered to the affiliated Prest-O-Lite at the price of 20 cents per pound. Before the move from Clendenin had been completed this program was radically revised. The price of isopropyl alcohol was cut to \$3.75 a gallon, that of acetone to 12 cents a pound.\* It was decided, therefore, to put emphasis on the manufacture of ethylene compounds, particularly ethylene glycol and its monoethyl ether, trade-named Cellosolve. Thus initial operation at Charleston was for ethylene, then ethylene chlorohydrin and dichloride.

To provide chlorine for this amended schedule, Carbide and Carbon Chemicals drew upon its neighbor, the Warner-Klipstein Chemical Company. Half of this plant's war-built capacity of 20 tons of chlorine daily was in excess of current demands, and a mutually advantageous contract was entered into for this surplus. Later the two companies cooperated to meet the bigger demands of Carbide and Carbon, so that the Westvaco operation, as the company was rechristened after reorganization of the Warner-Klipstein interests by William B. Thom in 1925, expanded with its chief customer's financial assistance.† Almost bankrupt before its reorganization, Westvaco was so enlarged under Thom's leadership that it became at one time the biggest electrolytic chlorine plant in the world.

By the end of 1925 the plant work on the new synthetic processes for producing organic chemicals had been almost wholly transferred from Clendenin to South Charleston. Production was being obtained on novel products and the problem arose of finding markets for them. Heading up this enterprise at that time were William F. Barrett and James A. Rafferty, as administrative leaders in New York. At Charleston, among others, were H. Earle Thompson, James W. McLaughlin, G. B. Landes, H. C. Holden, J. N. Compton, and R. N. Graham, all enthusiastic technical men who had been brought from the ranks of other Union Carbide units. J. G. Davidson was delegated to find the markets required to justify the volume, which Earle Thompson's engineering and Landes' production efforts had been able to develop. A Ph.D. in chemistry, Davidson decided that this should be entirely a chemical proposition, that the best approach to selling the new organic products would be through the technical men rather than by trying to impress purchasing agents. In building the sales staff, he chose only trained chemists and chemical engineers, who went out into the trade, met research men on their own ground, and talked a language that was completely new to the chemical purchasing profession.

\* Twenty years later, in the midst of World War II, isopropyl alcohol sold in the price range of 37½-66½¢ gal., and acetone, 6-7¢ lb., an illuminating footnote to the price history of organic chemicals within this general group. For price picture during 1920's, see Appendix IV.

† See Chap. 8.

By 1927 a further expansion of the plant was necessary and Blaine's Island in the Kanawha River was purchased. Besides the laboratory, the first construction there was a series of storage tanks, and with an eye to diversification of products, a petroleum refinery was designed to use the then-new vapor-phase cracking process.

The commercial trail-breaker of the new aliphatic chemicals was ethylene glycol. Conceived of as a new solvent, early introduced as a substitute for glycerin in the manufacture of low-freezing dynamite, it found its first great market as a tailor-made anti-freeze.\* It was initially marketed by the sister company, Prest-O-Lite, which gave it the trade name Prestone. With methanol and glycerin it challenged denatured alcohol for this growing market, and the four-sided battle royal was fought viciously for several years.<sup>30</sup>

Ethylene glycol seriously entered the field in 1926, after production was fairly under way at Charleston. In 1927 Carbide and Carbon's glycol was turned over for sale as an anti-freeze to another sister company, National Carbon, which priced it at \$5 a gallon. Though by a goodly margin it was the highest-priced anti-freeze, nevertheless an important glycerin factor, Parsons & Petit, acknowledged at the time that because of the definitely limited supply of their product, ethylene glycol had already won the competitive edge.<sup>31</sup> In 1927 domestic glycol production, which had been 10,000 pounds in 1920 and 5,000,000 pounds in 1926, passed 12,000,000.<sup>32</sup> Engaging in the contest with spirit, glycol anti-freezes were improved in every way possible to meet the exacting requirements.<sup>33</sup> An anticorrosive was added, then an anti-leak agent, and since this last caused foaming, also a foam preventive. In the winter of 1930 the improved product was launched by the National Carbon Company. A green dye was added to identify the product and studies were also initiated with the Army Air Corps to use ethylene glycol as a cooling agent for airplane motors. These tests were extensive and in the early 1930's it was announced that ethylene glycol had been found most satisfactory for liquid-cooled engines, forecasting the sealed, glycol-cooled aircraft power plants of World War II.<sup>34</sup>

While ethylene glycol was thus carving a niche in chemical commerce, its derivative, Cellosolve † (ethylene glycol monoethyl ether),

\* First prepared by Würtz in 1857 (*Compt. rend.* 45, 228), its use in dynamite was known since 1870 (Henry, *Ber.* 3, 529). For first commercial synthesis, see G. O. Curme, Jr., and C. O. Young, *Chem. Met. Eng.* 28, 169 (1923); use as anti-freeze, *Ibid. Ind. Eng. Chem.* 17, 1117 (1925); significant use in dynamite, W. H. Rickenbach, *Chem. Met. Eng.* 34, 296 (1927); industrial applications, H. B. McClure, *Ind. Eng. Chem., News Ed.* 17, 149 (1939).

† Patented as a solvent, U. S. Pat. 1,633,927, filed July 20, 1925, iss. to J. G. Davidson, June 28, 1927, ass. to Carbide and Carbon Chemicals Corp.

and other chemical relatives, were also winning their place in the trade. Cellosolve was one of the first fruits of a new direction which Carbide and Carbon research took at this time: the deliberate synthesis of materials with chemical and physical properties designed to meet specific requirements of users. In the lacquer industry's hunt for improved nitrocellulose solvents, mixtures of alcohol and ether had useful characteristics which were counterbalanced by the disadvantage of exceedingly rapid evaporation. Consequently a chemical was sought that would have the chemical properties of alcohol and ether, combined with a more tractable rate of evaporation as well as a mild odor. Thus Cellosolve was synthesized and other members of this family followed in logical sequence as the solvent-using industries began to define their requirements in more and more specific terms. Carbitol (diethylene glycol monoethyl ether) appeared in 1928, butyl Cellosolve and butyl Carbitol the same year, and methyl Cellosolve in 1929.<sup>35</sup>

This approach also led to the ethanolamines, tailor-made for the dye-stuff industry's need for a better material for "pasting" dyes in textile printing operations. The requirements of high boiling and hygroscopicity could be met by a material similar to glycerin; but which also would be an amine. The combination of these two chemical functions in one molecule resulted in the production of triethanolamine in 1928, and mono- and diethanolamine in 1932. So useful did these molecules prove that within ten years these three products were admitted to have "the greatest number of uses of any of the chemicals produced in our plant."<sup>36</sup> Production so increased that the initial price of triethanolamine of \$2.50 a pound was reduced to \$1.50 \* within a year.<sup>37</sup>

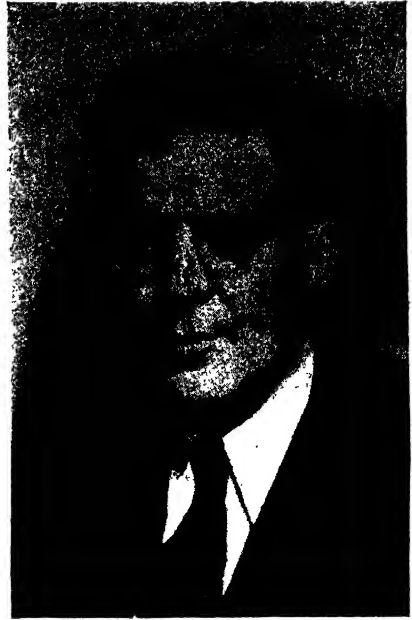
Similarly, the obvious needs of the coatings industry for a good, synthetic drying oil to substitute for linseed, tung, and other natural oils, inspired work that led unexpectedly to the development of the Viny-lite resins. Since linseed oil dries because of its unsaturated groups, a study of the polymerization and copolymerization of unsaturated hydrocarbons was started. The drying oil was not found, but a new series of synthetic resins resulted.<sup>38</sup>

New aliphatics from the Charleston plant multiplied notably during the two closing years of the 1920's. Beside the new amines and glycol ethers, there appeared in 1927 the ester, Cellosolve acetate, and the next year diethylene glycol and triethylene glycol. In 1929 acetone and isopropyl alcohol were offered commercially, together with dichloroethyl ether, dioxane, ethylene oxide, and vinyl chloride. A new chemical industry had been created. These aliphatics had not even been the proverbial "laboratory curiosities," but the dream of a few American

\* By 1940 it was down to 17½¢ lb.



WILLIAM J. HALE



EDGAR C. BRITTON



MARK E. PUTNAM

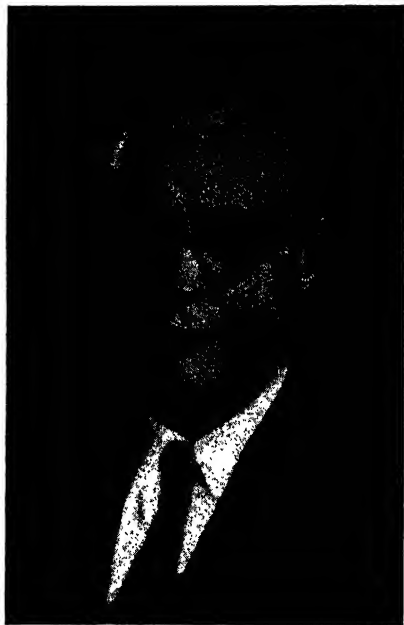


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C. OLIN NORTH



CARL N. HAND



LOUIS VEILLON

chemical prophets who envisioned the enormous possibilities in the unsaturated hydrocarbons derived from petroleum gas.

Just around the corner was the fulfillment of another chemical dream, the synthesis of ethyl alcohol. In the World War I emergency, two synthetic ethanol plants had been built in Germany and one each in England and France.<sup>39</sup> Postwar all these closed down. On May 4, 1928, Per K. Frolich, then assistant professor of applied chemistry at Massachusetts Institute of Technology and later with the Standard Oil Development Company, told a joint meeting of four chemical societies in New York that it had been demonstrated that not only methyl alcohol but ethyl, butyl, and amyl alcohols might all be synthesized from carbon monoxide by varying the catalysts.<sup>40</sup> Just a year later Prohibition Commissioner Doran issued a special permit to Carbide and Carbon Chemicals to test the commercial production of synthetic alcohol, not from CO, but from ethylene. Under this 30-day permit approximately 48,000 proof gallons were synthesized, denatured, and sent through trade channels for trial.<sup>41</sup> Shortly afterwards it was announced that the coming year the company planned to produce some five or six million gallons of which a fifth would be used in its own plant for its own processing.

In the evolution of hydrocarbon solvents, both of the saturated and unsaturated groups, chlorine carried a weighty load. Among the aliphatics it was the key reagent in the first step of the synthesis: at Carbide and Carbon in the production of ethylene dichloride \* and at Sharples in the chlorination of pentane.<sup>42</sup> Paralleling these came other chlorinated solvents.<sup>43</sup>

Carbon tetrachloride, the trail blazer, held its position against younger rivals, though an increasing proportion of its sales went to fire extinguishers. Most influential among the newcomers was trichloroethylene, promptly nicknamed "Tri," notable for its high solvent action and stability, its nonflammable and noncorrosive characteristics, the ease and economy of its recovery.<sup>44</sup> Commercial processes had been worked out in Germany and in England, based upon the treatment of acetylene tetrachloride (tetrachloroethane) with lime. In 1925 the Roessler &

\* Discovered in 1795 and known as the "oil of the Dutch chemists," ethylene dichloride only became commercially available in 1923 from Carbide and Carbon at 35¢ a lb., the price dropping to 25¢ in 1924, in the spring of 1926 to 10¢, and next fall to 6¢ in tankcar lots. This made it the cheapest chlorine solvent, comparable on a volume basis with carbon tetrachloride at 4.75¢, with trichloroethylene at 5.27¢, and acetylene tetrachloride at 4.65¢. Cheap ethylene dichloride in liberal supply was the keystone of the Carbide and Carbon development, but its influence extended far and wide. [See orig. ref., Deimann, Troostwyk, Bondt, and Louwrenburgh, *Crell's Ann.* 2, 195, 310, 430 (1795); also G. O. Curme, Jr., *Chem. Met. Eng.* 25, 999 (1927); R. T. Elworthy, *Ind. Chem.* 4, 276 (1928); D. H. Killeffer, *Ind. Eng. Chem.* 19, 636 (1927); U. S. Pat. 1,315,542, 1,315,545 (1919), 1,422,838 (1922), and 1,518,182 (1924), iss. to Curme, the first 2 being ass. to Union Carbide, the latter 2 to Carbide and Carbon.]

Hasslacher Chemical Company, which had previously imported large quantities, began the manufacture of trichloroethylene at Niagara Falls, introducing also for the first time tetrachloroethane.<sup>45</sup> As the price decreased, the use of this solvent spread from dry cleaning to degreasing and oil extraction and as an insecticide and fumigant.

The bellwether "Tri" had a flock of followers. The year before it was first made in this country, Dow put on the market trichloroethane and trichloroacetic acid, and the U. S. Industrial Chemical Company, ethyl chlorocarbonate.<sup>46</sup> *o*-Dichlorobenzene, by-product in the preparation of *p*-dichlorobenzene, reached an output of 1,000,000 pounds in 1927. It was recommended as a solvent and metal cleaner,<sup>47</sup> but failed to achieve significant commercial standing.\* Other cyclic solvents, produced by the high-pressure hydrogenation of various coal-tar intermediates, did register, however, and Tetralin (tetrahydronaphthalene) and Hexalin (hexahydrophenol), first made in Germany as substitutes for turpentine and to eke out motor fuel during the war, were prepared in commercial quantities in this country in 1924 by the Newport Chemical Works.<sup>48</sup> Of this same group, Dekalin (decahydronaphthalene) and Tetralol (tetrahydronaphthol) also appeared at this time.

Solvents of all types multiplied and ramified, while their uses increased as if by magic. The lacquer industry was particularly partial to the acetates, so that between 1923 and 1929 consumption of ethyl acetate, 85 per cent grade, increased from 16,970,972 to 55,155,247 pounds, while that of butyl acetate scored a hundredfold increase, from 351,041 to 30,667,187 pounds.<sup>49</sup>

Ethyl acetate, whose commercial production from acetaldehyde, an intermediate in the preparation of acetic acid from ethyl alcohol or acetylene, was announced by Shawinigan in 1926,<sup>50</sup> dropped behind some of the other, newer solvents.<sup>51</sup> This was attributed to reduced demand for artificial leather, due to the increasing percentage of closed cars and their use of other materials as seat coverings, and to the greater use in special fields of such solvents as Cellosolve, ethyl lactate,† butyl

\* Later, under U. S. Pat. 1,996,353 (1935), granted H. Seydel, it found important use as a disinfectant and aquatic weed control for irrigation ditches under the trade names, Benochlor and Cloroben.

† "According to my recollection there was a time in the middle 1920's when ethyl lactate, Cellosolve, and normal butyl acetate were the three prime competitors for the nitrocellulose lacquer solvent market. Butyl acetate came first and I do not remember which was the next, ethyl lactate or Cellosolve, but I think the two came upon the commercial scene at about the same time. For several years J. G. Davidson of Carbide, Don Keyes of U. S. Industrial Alcohol, and I used to tag each other around at American Chemical Society paint and varnish meetings and similar forums to extol the technical merits of our respective solvents. Time proved that Don Keyes was betting on a losing horse, but, from the standpoint of history, his work and that of his company was quite important in developing the solvents market. U. S. Industrial Alcohol was then a prime

propionate, and butyl and amyl acetates. The impressive growth of butyl acetate, on the other hand, represented only part of the increased consumption, for imports of this material, made in Germany from synthetic materials, increased so markedly that the chief American producer, Commercial Solvents, discontinued its production from butanol at the Terre Haute plant during the greater part of 1928.<sup>52</sup>

Another familiar solvent, previously in limited supply, that profited by the stimulation of this entire group, was methyl ethyl ketone, whose output increased greatly after it was produced from secondary butyl alcohol by the Standard Oil Company on patents for the catalytic dehydrogenation of alcohols to ketones by Carleton Ellis, H. D. Gibbs, M. D. Mann, and R. R. Williams. An interesting development was its production from acetone oil by a new process at the wood chemical plant of Norwich Chemical Company at East Smethport, Pennsylvania, in the spring of 1927.<sup>53</sup> This enterprise had been established the year previous by R. Kessler, Jr., to refine crude wood distillates and exploit the products along chemical lines. This was a revival of an old process. At the same time the availability of secondary butyl alcohol opened up the greater synthetic source, increasing the supply of this useful material which, due to the curtailment of acetone from acetate of lime, had become scarce.

New solvents from a new solvent producer were represented by the announcement of American Cyanamid, January 1928, of the commercial production of ethyl lactate and ethyl oxybutyrate.<sup>54</sup> In an entirely different field—solvents from naval stores—Hercules Powder in 1929 began marketing ethyl abietate.<sup>55</sup> Interest also revived in *p*-cymene (isopropyltoluene), the so-called "spruce turpentine" and a waste product from the sulfite digestion of spruce pulp in paper manufacture. During World War I, production of toluene from cymene had been attempted without worth-while results \* because of the indifference of pulp manufacturers to the recovery of this waste. Dr. Charles H. Herty, always alert to naval stores' opportunities, had belabored this profligate apathy.<sup>56</sup> Cymene was recognized as an excellent paint and varnish thinner and a useful solvent, and Dr. Ralph H. McKee worked out a practical synthesis of carvacrol from it.† However, it continued to be of academic interest only, although M. Phillips and M. J. Goss of the Bureau of Chemistry suggested it as an important improvement in paint removers.‡ None of these possible markets tempted the pulp industry

business factor in the lighter solvent field, i. e., ethyl acetate, and was determined to have something to fill out its solvent line." (Bruce K. Brown, to author, June 26, 1926.)

\* See Vol. II, p. 132; Vol. III, p. 356; also R. J. Moore and G. Egloff, *Met. Chem. Eng.* 17, 66 (1917); A. W. Schorger, *J. Am. Chem. Soc.* 39, 2671 (1917).

† U. S. Pat. 1,449,121 (1923).

‡ U. S. Pat. 1,580,914 (1926); see also Phillips and Goss, *Chem. Met. Eng.* 33, 745 (1926).

to recover a waste which at the time was estimated to be as much as 2,000,000 gallons each year.<sup>57</sup>

While such esoteric solvents roused discussion and literally scores of new materials were investigated, several old reliables continued to plow ahead. In spite of its unpleasant odor and rather high toxicity, carbon bisulfide, for example, forged on because of its use in the manufacture of viscose rayon. The Stauffer Chemical Company, which, in order to supply demand for bisulfide as a rodent exterminator and insecticide against Phylloxera (plant lice) in California vineyards, had first produced it on the West Coast, purchased in 1926 the Niagara Falls plant of the Niagara Smelting Corporation. This had been a war project of V. M. Weaver of Harrisburg, Pennsylvania, who projected a production of aluminum by the electrolysis of the chloride formed in chlorinating bauxite.<sup>58</sup> Ineradicable troubles with the chlorination furnace forced a change in plans and silicon and titanium tetrachlorides were produced for smoke screens and later sulfur chloride for war gas. When the demand for these munitions ended with the Armistice, the plant was converted to an electrolytic operation for the manufacture of a concentrated solution of calcium hypochlorite sold to neighboring paper mills. Later carbon tetrachloride by chlorination of carbon bisulfide was added.

Shrewd John Stauffer, whose roving eye saw possibilities in this Niagara Falls operation, took over the company after four years of patient negotiation. As he was quite apt to do, he left the subsidiary independent and intact. The Stauffer executive vice-president in New York City, Albert Walter,\* was elected president, but plant operations remained in the hands of G. D. Muggleton till 1929, when he resigned to take charge of the cornstalk paper plant at Danville, Illinois, and Paul S. Brallier,† formerly technical director, succeeded him. In 1928, in affiliation with du Pont, and still with an eye on carbon bisulfide, Stauffer established the Old Hickory Chemical Company on 100 acres of land north of the du Pont rayon operation, at the site of the big, wartime munitions works.<sup>59</sup> That same year the historic Taylor Chemical Company, organized in 1900 by E. R. Taylor to exploit his pioneering electrolytic process for the production of carbon bisulfide, changed hands. For some time past, its sales had been managed by the J. T. Baker Chemical Company, which now took over the operating management, with

\* Walter was born in Germany in 1875, and came to the U. S. in 1904. From 1906 on, his entire business career has been with Stauffer as dir. of plant building and officer in most of its subsidiaries. He became vice-pres. and gen. mgr. in 1933, pres. and bd. chmn. in 1942, and retired in 1946.

† A Pennsylvanian, trained at Penn State (B.S., 1916), Brallier became chief chem. at Niagara Smelting in 1916, after a brief experience with Aetna Explosives, and has been with the co. since. He has served as chmn. and secy. of the West. N. Y. Sect. of the Am. Chem. Soc.

H. H. Garis in command. Frank D. Berry, the former president of Taylor, remained as director, along with John T. Baker, J. L. K. Snyder, and Ralph A. Clark.<sup>60</sup>

Chloroform reached the apex of a commercial career that during the previous quarter century had increased its output 332 per cent, while its price had declined 58 per cent.<sup>61</sup> Principal makers continued to be Dow, Roessler & Hasslacher, and the Brown Company, while Belle Alkali also reported some production. Although output increased from 1,585,250 pounds in 1923 to 2,767,301 in 1929, as an anesthetic chloroform had already declined and as a solvent it suffered from numerous specialized rivals.<sup>62</sup>

The most illuminating instance of the new competition was furnished by a by-product of the soap kettle, glycerin, whose chief use was in dynamite, but also substantially as a solvent and emollient in the drug trade. Glycerin prices had been fluctuating and domestic supplies were regularly eked out by importation, largely from England and France. In 1926, when the Glycerin Producers' Association went out for the anti-freeze market, supported by a national advertising campaign, the price mounted to the highest point since the acute war shortage. This was an unfortunate coincidence, prompted by the temporary world shortage of this material caused largely by strikes in Great Britain.<sup>63</sup> The result caromed in all directions. The anti-freeze campaign was so successful that the use of glycerin increased 50 per cent. Imported material poured in to take its share in this invasion of the alcohol market, while at the same time the high price stimulated the competition of ethylene glycol. Furthermore, manufacturers of drug and toilet preparations went hunting for substitutes. The strong market of 1926 was turned in 1927 into a weak one supported by a very flabby demand, which was not helped when the largest consumer of dynamite glycerin, du Pont, and the Kentucky Alcohol Corporation, announced that they had ready for operation in their jointly owned Eastern Alcohol Corporation a process for the recovery of glycerin from molasses mash.\* This plant had a capacity of 10,000,000 gallons of alcohol a year, which it was reported would yield possibly as much as 4,351,000 gallons of glycerin at a recovery cost hinted to be from 12 cents to 15 cents a pound. The lowest cost soap manufacturers had ever achieved was 12 cents.<sup>64</sup> The tribulations of the glycerin refiners culminated quickly and were tellingly described by F. F. Jordan, vice-president of the Emery Candle Company, at the tariff hearings before the Ways and Means Committee, in 1929, when he said that since 1927 his company, though not the largest refiner, had suffered losses to the extent of \$1,000,000.<sup>65</sup>

\* S. K. Varnes, U. S. Pat. 1,626,986 (1927) and J. W. Laurie, U. S. Pat. 1,627,040 (1927), both ass. to du Pont.

A choice anticlimax to the exuberant developments of these years was the announcement of the Bureau of Chemistry that it would exhibit at the 1923 Chemical Exposition a newly discovered "universal solvent," news that inspired the ribald question in what container this mysterious chemical fluid would be displayed. This potent reagent was selenium oxychloride whose truly remarkable solvent properties had been investigated by Dr. Victor Lenher,\* professor at the University of Wisconsin.<sup>66</sup> The most tangible outcome of this interesting but overplayed discovery was that it suggested to Dr. Charles F. Kettering the line of research which led to tetraethyl lead.

Indicative of the effects of progress upon this industry was the formation, in the summer of 1929, of the Solvents Institute, Inc. Its founders were American Solvents & Chemical Corporation, E. I. du Pont de Nemours & Company, Franco-American Chemical Works, Kessler Chemical Corporation, Merrimac Chemical Company, U. S. Industrial Chemical Company, and Van Schaack Brothers Chemical Works; its objectives, technical rather than commercial. The first officers were Glenn L. Haskell of "U.S.I.," president; William Holter of Van Schaack, vice-president; J. M. Kessler, secretary-treasurer; and Robert T. Baldwin, executive secretary.<sup>67</sup>

#### REFERENCES

1. *Chem. Mkts.* 21, 127 (1927).
2. For surveys of solvent-lacquer developments during 1923-29, see R. A. Coolahan, *Chem. Record-Age* 7 (Mar. 23, 1925); B. R. Tunison, *Chem. Met. Eng.* 32, 93 (1925), 33, 25 (1926), 34, 46 (1927), 35, 51 (1928); C. L. Gabriel, *Ind. Eng. Chem.* 20, 1063 (1928); *News Ed.* 18, 980 (1940); E. W. Reid, *Ind. Eng. Chem.* 26, 21 (1934); C. Ellis, *Chem. Ind.* 43, 145 (1938); Brown and Crawford, *Survey of Nitrocellulose Lacquer*.
3. Gabriel, O. R. Brunkow, and B. K. Brown, memos to author; *Drug Chem. Mkts.* 12, 784 (1938); see also Kelly, *One Thing Leads to Another*, Chap. 5.
4. A. Orr, *Chem. Mkts.* 20, 702 (1927).
5. Tariff Comm., *Census of Dyes, 1923-29*.
6. Gabriel, *Ind. Eng. Chem.* 20, 1063 (1928).
7. *Ibid.*; Co. memo to author.
8. *Drug Chem. Mkts.* 13, 1676 (1923).
9. *Ibid.* 15, 1609 (1924); 18, 12 (1926).
10. *Ibid.* 18, 1077 (1926); *Chem. Mkts.* 20, 798 (1927).
11. *Drug Chem. Mkts.* 18, 1231 (1926).
12. Co. memo to author; *Chem. Mkts.* 19, 1251 (1926).
13. *Chem. Mkts.* 21, 421 (1927).
14. Gabriel, *Ind. Eng. Chem.* 20, 1063 (1928); G. L. Haskell, to author, June 24, 1946.
15. *Chem. Mkts.* 22, 590 (1928); Gabriel, *Ind. Eng. Chem.* 20, 1063 (1928).
16. *Chem. Mkts.* 25, 181 (1929); 26, 285 (1930).
17. For details of this amyl alcohol development, see S. D. Kirkpatrick, *Chem. Met. Eng.* 34, 276 (1927); D. H. Killefer, *Ind. Eng. Chem.* 19, 1078 (1927); L. H. Clark, *ibid.* 22, 439 (1930); E. E. Ayres, Jr., *Chem. Mkts.* 20, 706 (1927) and *Trans. Am. Inst. Chem. Engrs.* 22,

\* Noted for his researches in selenium and tellurium, and prominent in the affairs of the Nat. Res. Council, Dr. Lenher died in June 1927, after some 30 yrs. of teaching chemistry.

- 9 (1929); W. Haynes, *Chem. Ind.* 37, 333 (1935).
18. Co. memo to author; *Drug Chem. Mkts.* 18, 548 (1926); Tariff Comm., *Census of Dyes, 1929*, p. 134.
19. *Chem. Mkts.* 21, 494 (1927).
20. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929, Sched. 1, June 1929, p. 186; *Drug Chem. Mkts.* 18, 1229 (1926).
21. R. H. French, to author, June 10, 1946; *Chem. Met. Eng.* 34, 328 (1927); *Chem. Mkts.* 20, 127, 610 (1927).
22. *Chem. Mkts.* 20, 464 (1927).
23. Tariff Comm., *Census of Dyes, 1923-29*.
24. D. B. Keyes, *Chem. Mkts.* 20, 705 (1927); *Ind. Eng. Chem.* 19, 521 (1927); H. C. Fuller, quoted in *Drug. Circ.* 14 (Feb. 1929).
25. J. G. Park, *Chem. Mkts.* 20, 704 (1927). For isopropanol developments, see also Keyes, *ibid.* 756; B. T. Brooks, *Ind. Eng. Chem.* 27, 278 (1935); Gabriel, *ibid.*, *News Ed.* 19, 132 (1941); L. Burgess, *Trans. Am. Electrochem. Soc.* 49, 253 (1926); Brooks, *Non-Benzenoid Hydrocarbons*; Ellis, *Chemistry of Petroleum Derivatives*; Egloff, *Reactions of Pure Hydrocarbons*.
26. E. H. Killheffer, to author, July 16, 1946.
27. *Drug Chem. Mkts.* 16, 647 (1925); Brooks, *Ind. Eng. Chem.* 27, 278 (1935).
28. L. du Pont, to author, July 25, 1946.
29. Primary sources are MS History of Carbide and Carbon Chemicals Corp., by J. N. Compton, Oct. 4, 1937 (made available to author by Dr. Geo. O. Curme, Jr.), and series of articles in the house organ, *Carbide News*, Feb., Apr., June, July 1939; see also *Chem. Met. Eng.* 40, 564 (1933); *Chem. Ind.* 36, S129 (May 1935); Brooks, *Ind. Eng. Chem.* 31, 515 (1939); C. M. A. Stine, *ibid.* 32, 137 (1940); S. B. Self, *Barron's* 13 (Dec. 4, 1939), 16 (Sept. 16, 1940); M. B. Chittick, *Producers' Monthly* 29 (May 1940).
30. *Chem. Met. Eng.* 38, 22 (1931).
31. *Ind. Eng. Chem., News Ed.* 11 (Oct. 20, 1925); Killeffer, *Ind. Eng. Chem.* 18, 1043 (1926); C. A. Taylor and W. H. Rinkenbach, *ibid.* 676; *Drug Chem. Mkts.* 18, 12 (1926), 19, 999 (1926), 20, 724 (1927), 21, 45 (1927); *Drug. Circ.* 10 (Jan. 1926).
32. H. S. Taylor, *Chem. Mkts.* 27, 360 (1930); T. H. Fairbrother, *Ind. Chemist* 4, 179 (1928).
33. *Carbide News* 9 (Feb. 1939).
34. *Chem. Mkts.* 24, 293 (1929); 25, 148 (1929).
35. *Carbide News* 13 (Feb. 1939); 10 (Apr. 1939).
36. *Ibid.* 11 (Apr. 1939).
37. H. F. Robertson, *J. Soc. Chem. Ind.* 59, T606 (1940).
38. *Carbide News* 11 (Apr. 1939); see also Chap. 21.
39. *Chem. Met. Eng.* 34, 125 (1927); W. N. Watson, *ibid.* 37, 161 (1930); *Chem. Trade J.* 79, 65 (1926).
40. *Chem. Met. Eng.* 35, 316 (1928).
41. Tariff Comm., *Census of Dyes, 1928*, p. 133; *Drug Mkts.* 25, 233 (1929).
42. Keyes, *op. cit.* 758.
43. P. S. Brallier, *Ind. Eng. Chem.* 33, 155 (1941).
44. P. J. Carlisle and T. Coyle, *Chem. Mkts.* 29, 243 (1931).
45. *Ind. Eng. Chem., News Ed.* 15 (May 20, 1925); *Drug Chem. Mkts.* 16, 870 (1925).
46. Tariff Comm., *Census of Dyes, 1924*, p. 124.
47. P. H. Groggins and W. Scholl, *Ind. Eng. Chem.* 19, 1029 (1927).
48. Tariff Comm., *Census of Dyes, 1924*, p. 27; Killeffer, *Ind. Eng. Chem.* 17, 999 (1925); J. F. Schuster, *Drug Chem. Mkts.* 16, 565 (1925); *Chem. Mkts.* 27, 592 (1930).
49. Tariff Comm., *Census of Dyes, 1923-29*.
50. Gabriel, to author, June 19, 1946; *Drug Chem. Mkts.* 18, 553 (1926).
51. Tunison, *Chem. Met. Eng.* 33, 26 (1926).
52. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 7, 1929, p. 188.
53. *Chem. Mkts.* 19, 528 (1926); 20, 635 (1927).
54. *O.P.D. Repr.* 52 (Jan. 23, 1928).
55. *Chem. Mkts.* 22, 66 (1928). For description of process, properties, uses, see A. C. Johnston, *Ind. Eng. Chem.* 21, 688 (1929).
56. *Ind. Eng. Chem.* 10, 1 (1918).
57. Groggins, *Chem. Met. Eng.* 34, 291 (1927); *Ind. Eng. Chem.* 19, 338 (1927); *O.P.D. Repr.* 30 (Feb. 21, 1927).



58. Brallier, to author, July 8, 1946; Haynes, *Chem. Ind.* 36, 114 (1935).
59. *Rayon* 27 (June 1, 1928); *Chem. Mkts.* 23, 387 (1928).
60. *O.P.D. Repr.* 49 (Dec. 24, 1928).
61. *Chem. Mkts.* 20, 708 (1927).
62. Tariff Comm., *Census of Dyes, 1923-29*.
63. *Chem. Mkts.* 19, 262 (1926), 21, 490 (1927); *Drug Mkts.* 20, 373 (1927); *Chem. Met. Eng.* 34, 266 (1927).
64. *Drug Mkts.* 20, 735, 743 (1927), 21, 12 (1927); *Chem. Mkts.* 21, 724 (1927).
65. Hearings Ways & Means Comm., *op. cit.*, p. 154.
66. V. Lenher, *J. Am. Chem. Soc.* 43, 29 (1921), 44, 1664 (1922); *Am. Druggist* 56 (Sept. 1923).
67. *Chem. Mkts.* 25, 69 (1929).

## Chapter 13

### CRUDES AND INTERMEDIATES

COAL-TAR CHEMICALS MOVE INTO NEW, BIG-TONNAGE FIELDS—STEEL COMPANIES RECOVER OWN CRUDES, OLDER DISTILLERS EXPAND—INTERNATIONAL COMBUSTION BUILDS LOW-TEMPERATURE CARBONIZATION PLANT—TOXICITY OF BENZENE STUDIED—DOW MAKES PHENOL FROM CHLOROBENZENE—DUTY ON PHENOL AND CRESYLIC ACID CUT—NEW METHODS AND DERIVATIVES FOR ANTHRAQUINONE, ANILINE, NAPHTHALENE, DIPHENYL—MORE INTERMEDIATES, WITH GREATER OUTPUT AND FEWER PRODUCERS.

**A**BOUT 1920 AN EPOCHAL CHANGE occurred in the American coal-tar chemical industry. Its products began moving out of the somewhat limited area of synthetic dyes and medicinals into the big-tonnage fields of synthetic plastics and resins.

During the half century preceding World War I, the chemistry of coal tar had been closely identified with German science. Though benzene had been discovered by Michael Faraday and the first coal-tar dye by William Perkin, it was August von Hofmann, Victor Meyer, Adolph von Baeyer, their students and followers, who took over the domain of coal-tar chemistry and made it Germany's own. Of the many coal-tar chemicals exploited by German firms, the majority were colors and pharmaceuticals. Still we should not forget that coal tar also gave us manufactured shingles and roofing sheets, phenol disinfectants and creosote wood preservatives, and made our paved highways possible.

During the war coal-tar explosives leaped to a temporary commanding position. Having had practically no coal-tar chemical industry, we emerged from the struggle with a coke-oven production more than ample to provide all peacetime needs for crudes and an unwieldy surplus of the munitions-making intermediates, benzene, toluene and phenol.\* The familiar fears of overproduction, glutted markets, and ruinous liquidation that worried many chemical leaders oppressed the makers of intermediates.

About 1920, however, new coal-tar derivatives began moving into new areas of consumption, one of the original chemical events of this decade. The amazing development of synthetic plastics and resins, first the phenolics and later the Glyptals, shifted the center of gravity from the intermediates aniline and beta-naphthol, great starting points of dyes and

\* For U. S. production of coal-tar crudes, 1923-29, see Appendix XXXV; for intermediates, Appendix XXXIV.

medicinals, to phenol and phthalic anhydride. Despite price reductions of roughly 50 per cent, the output of both aniline and beta-naphthol remained virtually constant during the next twenty years. In sharp contrast, between 1923 and 1929, sales of phenol and phthalic anhydride increased, respectively, from 2,180,244 pounds to 19,938,503 and from 2,091,100 pounds to 7,450,037. Both were to score even greater advances during the thirties.

Accompanying these growths in output were impressive declines in price. After the war surplus had been absorbed in 1923, the price of U.S.P. phenol, in drums, advanced to an abnormal high of 58 cents, dropping, however, to a low of 12  $\frac{3}{4}$  cents in 1929, after synthetic production was resumed. Phthalic anhydride, which during 1923 declined from 40 cents to 25 cents, was further lowered to 16 cents by 1929.\*

These figures are but the outward and visible sign of a remarkable technical and commercial transformation. New processes were involved that revolutionized whole sectors of coal-tar chemical technique. The demand for phenolic resins not only required all the available crude cresols, which were largely imported from England, but it compelled a great synthetic production of phenol. A new process based on the chlorination of benzene, was perfected, which promptly became competitive with the older sulfonation operation. Production of phthalic anhydride by the Gibbs-Conover-Wohl process, based on direct oxidation of naphthalene, resulted in the first significant American deviation from German coal-tar practice.† It replaced anthracene as the starting point in the manufacture of vat dyes. It made commercially feasible the phthalic-glycerin resins.

Employment of these intermediates in plastics and resins brought them into a field of almost limitless consumption. The need for colors and for medicines is relatively fixed. A pound of dye may suffice for many hundred yards of cloth and its cost is then but a fraction of the price of the finished goods. There are fashions in medicines as in clothes, and one therapeutic agent often replaces another with surprising rapidity, but save when a devastating epidemic smites, the gross annual sale of drugs varies but little from year to year.

Demands for plastics and resins have no such ceilings; their consumption depends only upon the skill and ingenuity of scores of manufacturers in many industries. Although not always discovered by American chemists, we have made the plastics our own much as the Germans a generation before had made the coal-tar chemicals theirs. Applications of plastics in this country have been the most diversified and widespread; their output here far exceeds that in any other land.

\* See Appendix IV for low-high price range, 1922-29.

† See Vol. III, p. 222.

During the early 1920's, by-product coke ovens at steel furnaces and municipal gas plants were installed independently of any consideration of the chemical industry's requirements for coal-tar crudes. Between 1923-29, excepting 1924, total production of coke exceeded 50,000,000 tons annually, reaching 59,883,845 tons in 1929, and surpassing the previous all-time record of 1918. In 1923 by-product ovens accounted for 37,527,000 net tons of coke; in 1929, 53,411,826.\* For the corresponding years, the output of beehive coke dropped precipitously from 17,960,000 to 6,472,019 net tons. Obviously the economics of by-product ovens, whether operated for metallurgical coke or for city gas, had been thoroughly established in the minds of the postwar generation of steel executives who were fast learning the difference between an ingot and a faggot and whose decisions were becoming more chemically minded. As indicating the standardization of technique, it is interesting to note that 95 per cent of the installations after 1923 were of Koppers-Becker ovens.<sup>1</sup> The first installation of this type, which was invented by Dr. Joseph Becker, was an experimental battery of five ovens in 1922, at the plant of the Chicago By-Product Coke Company, by the Koppers Company. It involved an entirely new heating system which doubled the coke capacity, a turning point in oven design.<sup>2</sup>

With the installation of new and additional ovens came changes in the handling of the by-products. Coking plants continued in the main to sell tar to refiners and to market light oils and sulfate of ammonia through selling agents. United States Steel was the first to break away from the distillers and established at Clairton, Pennsylvania, what was to become the largest individual plant in the country from the point of view of tar distilled. About the same time Inland Steel installed its own tar-distilling and refining plant at Indian Harbor. As the demand for toluene and xylene grew, more steel companies began stripping these crudes from their "motor benzol," till by 1927 half of the available material—some 4,000,000 gallons of toluene and 2,000,000 gallons of xylene—was so recovered.<sup>3</sup> Simultaneously the use of coke-oven gas for municipal heating and lighting increased at the expense of water and retort gas, with a corresponding increase in the quantity of coke-oven tar.<sup>4</sup> Competition in manufactured gas was intensified by the introduction of bottled hydrocarbon gases, butane and propane, and by the extension of natural gas pipelines from the Louisiana-Oklahoma fields to large cities in the Middle West.<sup>5</sup> The waning prestige of water gas was only partly restored by the use of automatic processes employing bituminous coal

\* Year by year by-product coke production recorded in *Mineral Industry* was: 1924, 33,983,568 net tons; 1925, 39,912,159; 1926, 44,376,586; 1927, 43,884,726; 1928, 48,315,025. This source also lists beehive coke production figures.

for the solid fuel and by the addition of propane and butane for enrichment.<sup>6</sup>

The Koppers Company became more active as a refiner of tar and producer of chemicals from the coal-tar distillates. In 1920 it had acquired a 25 per cent interest in the American Tar Products Company,\* adding to its six existing tar-distillation plants a new one at Chicago in 1922, and in 1925 assumed controlling interest.<sup>7</sup> That same year, the Semet-Solvay Company purchased a coke-oven plant in Detroit and the benzol plant at Syracuse from the Solvay Process Company,<sup>8</sup> the next year transferring to this affiliate its own plant at Solvay, New York, which manufactured ammonium bicarbonate and chloride, benzaldehyde, benzyl chloride, monochlorobenzene, and *p*-dichlorobenzene.† In 1927 the company separated its coke-oven and its chemical activities by establishing the Semet-Solvay Engineering Corporation which took over the Engineering Department of Semet-Solvay and acquired the Steere Engineering Company.<sup>9</sup> Organized in Michigan in 1914, Steere was one of the largest builders of municipal gasworks, tanks, and similar equipment with a plant at Owosso, Michigan. At the same time Allied Chemical & Dye, the parent company of Semet-Solvay, which owned 75 per cent of the stock of the Ashland By-Product Coke Company, offered the minority holders par for their stock and subsequently turned the operations at Ashland, Kentucky, and Ironton, Ohio, over to Semet-Solvay.<sup>10</sup>

The established tar refineries expanded operations and several new firms entered the business. The most interesting of these was the Neville Company, originally incorporated in 1925 for \$50,000 as the Neville Chemical Company, by Harvey N. Dauler,‡ W. S. Gardiner, and Edwin Hodge, Jr.<sup>11</sup> A plant was established at Neville Island and crudes were drawn from adjacent Pittsburgh steel companies. The first products were coal-tar solvents and coumarone-indene resins in which the Barrett Company had pioneered prewar. Ready markets were found in composition floor tiles, protective coatings, bubble chewing gum, and rubber products. Among the dealers in crudes and light oils, two new firms were

\* Inc. in Pa., 1914, to buy and process coal tar, and later the nucleus of the Koppers' Tar & Chemical Div. At this time the chem. dir. of American Tar Products was Edmund O. Rhodes, one of the first Industrial Fellows at U. Kan. under Robert Kennedy Duncan.

† "Semet-Solvay owned coke ovens, but never did any tar distillation or refining itself. Both before and after the formation of Allied, all its tar went to Barrett, which was overwhelmingly the big tar distiller and around 1919 or 1920 handled 80-90% of the coke-oven tar not burned by the producers. American Tar Products was a minor influence in the industry at this time and only began to grow after Koppers took an interest in it." (J. M. Weiss, to author, July 19, 1946.)

‡ Dauler, moving spirit and pres., had been in the petroleum business with Gulf Refining, Petroleum Products, and Beaver Refining, prior to establishing the Dauler Oil Co. in 1919. Gardiner has been secy.-treas. since the formation of Neville.

established by former Barrett men, Jayne & Sidebottom,\* and the Hydrocarbon Products Company. The former was organized in 1922 and the partnership dissolved in 1925.<sup>12</sup> Hydrocarbon Products, under the aggressive management of its founder, C. Warren Force,† has maintained its position in this highly complicated, competitive field. An unusual excursion into the coal-tar field was that of Henry L. Doherty & Company, which in 1924 incorporated a subsidiary, the General Atlas Chemical Company, capitalized at \$1,000,000, to manufacture from coal, coal tar, tar oil, ammonia, coke, and their by-products.<sup>13</sup>

Among the older tar refiners in the Middle West, the Republic Creosoting Company, which had been established by Peter C. Reilly ‡ in 1905, organized a chemical research department at its Minneapolis plant in 1918. In 1920 the department's quarters were moved to Indianapolis and became a major unit of the organization. Republic Creosoting markedly diversified its products during the twenties as a result of its own research, notably in flotation agents, wood preservatives, tar acids, and carbon products. This research, which had been organized by Ira H. Derby, moved in 1930 to a new laboratory building designed by Carleton B. Edwards, the assistant director. The Reilly Chemical Company was established in 1931 as a subsidiary of Republic Creosoting, to handle the coal-tar chemicals produced by both companies.<sup>14</sup>

Another old Midwest tar refiner, the F. J. Lewis Manufacturing Company, producers of coal-tar derivatives since 1887, added to plants at Fairmont, West Virginia; Dover, Ohio; Granite City and Chicago, Illinois; and Chattanooga, the Butterworth-Judson Company plant at Newark,<sup>15</sup> which was purchased at the receivers' auction for \$855,000.‡

\* David W. Jayne, son of the coal-tar pioneer, Harry W. Jayne, had been with Barrett since his graduation from U. Pa., 1902, being at the time mgr., Chem. Dept. Herbert G. Sidebottom (1892-1930), a Philadelphian with a B.Chem. from Cornell (1913), was briefly with du Pont before joining Barrett's tech. staff, rising to mgr., Tech. Serv. Dept., in 1922. After dissolution of their partnership, Jayne went to American Tar Products and in 1928 to the Development Dept. of du Pont. Sidebottom became vice-pres., Newark Varnish Works; later mgr., Sales Research Dept., Sun Oil, and in 1927 asst. mgr., L. Martin & Co., and asst. to pres. of the affiliated Darco Sales Corp. He was secy. of the N. Y. Sect., Am. Chem. Soc., 1916-22; of the Paint, Oil & Varnish Assoc., 1920-25; and of the Chemists' Club (N. Y.), 1921-25.

† Force, who went to work for Barrett in 1898 at eighteen, is one of the forceful, outspoken "characters" of the industry, a shrewd, hard worker, whose surprising hobbies are the collection of first editions, Chinese ivories, and antique Buddhist illuminated scrolls, in each of which he is a recognized authority.

‡ Reilly entered the tar business as stenographer for H. H. Childs of the Mica Roofing Co., succeeded by the National Coal Tar Co. When this bought the Western Chemical Co., Indianapolis, in 1895, Reilly went as mgr. In 1900, a year after the Barrett Co. acquired National, Reilly organized the Western Creosoting Co., later the Republic Creosoting Co. He is a dir., Real Silk Hosiery Mills, Union Trust Co., Butler U., and pres., Bd. Lay Trustees, Notre Dame U., which awarded him an LL.D. in 1939.

§ Price \$757,000, according to *Chem. Met. Eng.* 32, 297 (1925).

In 1928 the Lewis firm was absorbed by the International Combustion Engineering Corporation of New York, and its name changed to the International Combustion Tar & Chemical Corporation. The year previous, the parent company had built a low-temperature, coal-carbonization plant at New Brunswick, New Jersey, to handle approximately 250,000 tons of bituminous slack coal a year in its initial eight units. It contracted to supply the Public Service Corporation of New Jersey with a minimum of 10,000,000,000 cubic feet of gas for the next ten years and to furnish 6,000,000 gallons of coal tar to the six Lewis plants. It was additionally proposed to produce 2,750,000 gallons of the heavier distillates to be marketed as wood preservatives, disinfectants, flotation agents, and plastics ingredients.<sup>16</sup> In 1929, however, the International Combustion Engineering Corporation and its two subsidiaries, the Tar & Chemical and the Combustion Engineering Corporations, went into a receivership on the application of Bethlehem Steel.<sup>17</sup>

This New Brunswick plant was the first large-scale, low-temperature carbonization operation in the United States, an adaptation of the plant at Essen, Germany. Both here and in England low-temperature carbonization, which had its inception in the experimental work of Professor Parr \* at the University of Illinois back in 1900, experienced a great revival in interest due to its adoption in Germany during World War I to supply liquid motor fuels.<sup>18</sup> While low-temperature methods were at this time premature in this country, their investigation indicates an interest in coal-tar technology which had practical results. In 1923, for example, Semet-Solvay engineers perfected a new process for removing high-boiling, benzol-free residues from crude light oil, and in 1926 the Barrett Company introduced a direct recovery system for products from coal tar at the plant of the Iron-ton By-Product Coke Company.<sup>19</sup> Based upon the very rapid distillation of tar by the use of hot gases from the coke ovens, this method markedly increased the yield of creosote oil and made commercially available new varieties of coal-tar pitch. That same year the Koppers Company pioneered in the commercial development of gas dehydration.<sup>20</sup>

During the twenties, two alkali companies installed new by-product coke plants, Diamond at Painesville, Ohio, in 1924,<sup>21</sup> and Michigan at Wyandotte, in 1927.<sup>22</sup> Abroad, the Monsanto Chemical Works' subsidiary, Graesser-Monsanto, Ltd., purchased in 1929 the Sunderland works of Brotherton & Company, which added to its British list of prod-

\* Samuel Wilson Parr (1857-1931) studied at Illinois, Cornell, Berlin, and Zurich, and was awarded an hon. D.Sc. by Lehigh in 1925. He was prominently identified with Ill. water supplies and coal resources and was the inventor of calorimeters for measuring the heat values of coal and hydrocarbon gases. Past pres. of Am. Chem. Soc., he is author of *Chemical Examination of Water, Fuel, Flue Gases and Lubricants*, and received the Chandler medal, 1926.

ucts creosote, naphthalene, benzene, toluene, xylene, solvent and high-flash naphthas, refined pyridine, and pitch.<sup>23</sup>

Conspicuous activity in the city gas field was evidenced by the installation of 25 Semet-Solvay ovens at Hamilton, Ontario, for the Hamilton By-Product Coke Company, in 1924,<sup>24</sup> and in 1927 by three important projects in this country: the New Haven Coke Company, Koppers subsidiary, with 58 by-product ovens located at the waterfront;<sup>25</sup> the Virginia Domestic Coke Corporation of Richmond, which installed a \$2,000,000 plant;<sup>26</sup> and the North Shore Coke & Chemical Company at Waukegan, Illinois, which contracted to supply the North Shore Gas Company for 25 years with an initial daily output of approximately 3,000,000 cubic feet of gas.<sup>27</sup>

Impressed with by-product oven yields of 75 per cent coke, 10,000 cubic feet of gas, 5 gallons of tar, 2 to 3 gallons of light oils, 20 to 25 pounds of ammonium sulfate per ton of coal, compared with nothing but 66 per cent of coke from the beehive ovens, the steel industry made notable additions to its by-product oven capacity. In the single year of 1926 the Koppers Company wrote orders from 15 different steel plants for 826 Becker-type ovens with a total annual capacity of 7,500,000 tons of coal. Among these was the Carnegie subsidiary of United States Steel at Clairton, Pennsylvania, which by adding 348 units, became the largest by-product coke plant in the world.<sup>28</sup>

Until 1927 the sale of motor benzol continued unabated, reaching a total that exceeded 100,000,000 gallons, an invaluable safety valve for the overproduction of light oils during these years.<sup>29</sup> Thereafter, however, several influences began to contract this output as a motor fuel blend. The most direct of these was tetraethyl lead with its superior anti-knock properties, but there were other restraining factors. Important among these was the agitation against the health hazard involved in the use of benzene.

In the spring of 1923 the Chemical and Rubber Sections of the National Safety Council appointed a joint Committee on Benzol headed by Dr. Charles-Edward A. Winslow of the Yale Medical School, upon which served Hamilton Bradshaw, assistant chemical director of du Pont, and John M. Weiss, representing the Manufacturing Chemists' Association.\* After three years' conscientious study during which it collected proof of at least 15 fatal and 83 nonfatal cases of benzene poisoning in the years immediately preceding 1925, the Committee concluded that the hazard was a grave one, in fact a major problem of

\* Other members of the Comm. were Leonard Greenburg, Pub. Health Serv.; W. S. Paine, Aetna Life Insurance Co.; J. W. S. Brady, Mass. General Hosp.; A. C. Fieldner, Bur. Mines; C. F. Horan, Hood Rubber Co.; L. E. Weber, consulting chem.; John R. Dexter, Mass. Dept. Labor & Industries; J. Newton Shirley, Hood Rubber; and J. J. Batchelor, Yale Sch. Medicine.

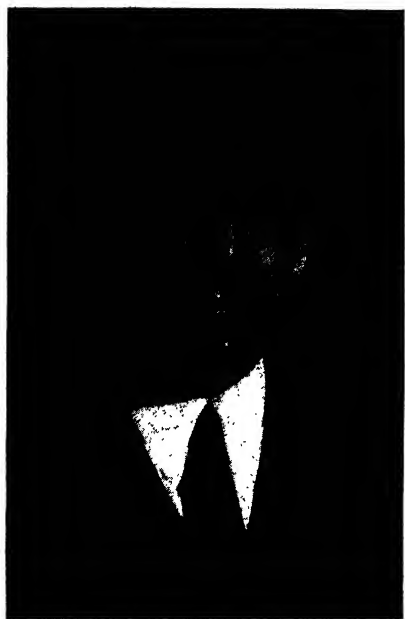


industrial hygiene. Its report, published May 1926, found that despite the greatest industrial use of benzene in the chemical industry, the health hazard here was the lowest because the material was commonly used in enclosed apparatus with less exposure to workmen than was the case in the can-sealing, rubber, and artificial leather industries. The constructive recommendation was that wherever possible the less dangerous homologs, toluene and xylene, and high-flash naphtha be substituted. Where the use of benzene was obligatory, forced exhaust ventilation was advised and regular medical supervision urged. Upon these findings, the National Bureau of Casualty & Insurance Underwriters issued an almost simultaneous report embodying identical recommendations.<sup>30</sup>

The industry took these admonitions to heart. Greater use of toluene as a solvent and as a volatile thinner in nitrocellulose lacquers, created a demand that encouraged by-product coke-oven operators to strip motor benzol of both toluene and xylene. This encouraged the growth of the primary intermediates such as *o*- and *p*-toluidine. The supply of pure benzene was also correspondingly increased and the chemical employment of this crude, chiefly in the production of phenol, fortunately was also stepped up. The benzene capacity of the country, enormously expanded by the war, had been still further increased. As early as 1923 the Portland Gas & Coke Company added equipment for the purification of light oils to produce about 9,000 gallons of benzene daily, the first commercial-sized recovery plant on the West Coast.<sup>31</sup> In 1927 Semet-Solvay built a \$400,000 benzol plant in Ontario for the Hamilton By-Product Coke Company.<sup>32</sup> Doubly interesting both in its backer and its process was the benzene recovery undertaken by the Ford Motor Company by the Piron-Caracristi low-temperature process, deliberately installed for its large yield of 10 gallons of benzol, 20 pounds of tar, 20 pounds of ammonium sulfate, and 3 gallons of creosote per ton of coal.<sup>33</sup>

In 1923 phenol became with dramatic suddenness "the most interesting commodity on the chemical market."<sup>34</sup> In four years the Armistice Day stock of 27,000,000 pounds,\* estimated to be six years' supply, had gone into consumption and the price began to soar. Within twelve months spot quotations rose over 400 per cent, to 50-58 cents. Synthetic production by the sulfonation of benzene, which had reached its greatest capacity of 100,000,000 pounds annually during the war, had been entirely canceled out, and the only considerable recovery of natural phenol was being made by the Barrett Company.<sup>35</sup> Due to rail and coal

\* The government-owned stock was turned over to Monsanto to be sold at the allotted price of 12¢ lb. Bakelite bought 12,000,000 lb. and Dow 1,000,000, at the fixed price but with the price equalized at St. Louis, though this was Dow-made phenol stored just outside the fence of the Midland plant. (Sandford Brown and W. J. Hale, to author, 1946.)



SANDFORD BROWN



*Chemical Industries*

JAMES M. SELDEN



HARVEY N. DAULER



BYRD WALKER



LOUIS B. FORTNER



CHARLES H. DUNKER



GRAHAM N. GLEYSTEEN



SIDNEY R. DAVID

strikes, unusually large quantities of crude coal tar had been used for fuel in the steel industry, cutting down this limited supply. Consumers could get but little relief from imports because of the high tariff rates, 7 cents a pound and 40 per cent ad valorem, added to high foreign prices induced by a shortage of natural phenol in Great Britain, then our principal supplier.

With the soaring price, however, wartime producers of synthetic phenol resumed operations. The first to offer material was the Heyden Chemical Company, which by June 1923 was producing 5,000 pounds daily.<sup>36</sup> Monsanto completely rebuilt its phenol plant;<sup>37</sup> four additional companies entered into production; the output—3,311,000 pounds in 1923—jumped to 14,734,000 pounds in 1925. This increase came almost entirely from synthetic phenol.<sup>38</sup> By December 1923 the price had returned to 25 cents a pound, a year later to 21 cents, and during the last five months of 1926 to 17 cents. In the meantime two new elements had been injected into this spectacular market situation.

At the height of the shortage the largest domestic consumer of phenol, the Bakelite Corporation, began building a synthetic phenol plant at Painesville, Ohio. It was announced that production would be greater than its requirements and that the excess would be offered for sale.<sup>39</sup> This was, of course, a threat as well as a promise, and it was made good, for the Tyrer process \* plant was speeded to completion and after some preliminary difficulties reached an output early in 1925, of 1,250,000 pounds monthly.<sup>40</sup> But Dr. Leo Baekeland, the very active head of Bakelite, had never aspired to manufacture his own raw materials. From the beginning he purchased his formaldehyde from Roessler & Hasslach, actually building his first plant on that company's property. Accordingly, in 1928 he made contracts for his phenol requirements, a million pounds annually, with Dow and Monsanto. A similar contract with Dow was soon signed by the Newport Manufacturing Company for phenol to manufacture Hexalin (hexahydrophenol).<sup>41</sup> Both orders were the result of the new synthetic phenol process developed under Dr. William J. Hale,† Dow's dynamic director of organic research.

\* D. Tyrer, U. S. Pat. 1,210,725 (1917); see also A. Guyot, *Chimie & industrie* 2, 879 (1919).

† From 1919 to 1934 Hale was the inspiring leader of Dow's organic chemical progress and besides this phenol process contributed novel commercial syntheses of aniline and acetic acid. A sound chemist trained at Miami U. (A.B., A.M., 1897; LL.D., 1937) and Harvard (A.B., 1898; A.M., 1899; Ph.D., 1902), a fellow at Berlin and Göttingen (1902-3), "Billy" Hale is famous for thinking originally and speaking frankly. From 1904-19 he taught at U. Mich., rising to assoc. prof. chem. and since 1934, when he retired, he has been consultant to Dow and pres., National Agrol Co. His book, *Farm Chemurgic*, launched this idea, and he is the author of *Chemistry Triumphant*, *Prosperity Beckons*, and *Farmward March*, provocative works in which he expounds his unorthodox chemico-economic ideas. For his own account of the phenol development, see Appendix XXXVI.

For a long, long time many chemists had tried to pin down the hydrolysis of chlorobenzene to a commercial process for the production of phenol. In 1917 the first important American contribution was made by J. W. Aylsworth; \* an hydraulic accumulator for maintaining the liquor at a continuous pressure. Apparently this apparatus was never put into actual plant practice and it remained for W. J. Hale and Edgar C. Britton † of the Dow staff to evolve a workable method,<sup>42</sup> whose commercial efficiency was greatly increased by the use of a heat-exchange system based on the use of a surrounding tubular enclosure through which the incoming reactants entered.<sup>43</sup> The Dow plant operating this new process swung into full commercial production in 1927, when the total output of this intermediate was reported by the *Census of Dyes* to be 8,041,082 pounds. By 1929 this figure had almost trebled: 24,177,618 pounds.

This conspicuous growth was noteworthy in view of the sharp cut in the tariff rate in 1927. Back in 1923, when the shortage was critical, the proprietary drug house of James F. Ballard, Inc., ‡ of St. Louis, petitioned the Tariff Commission for a reduction in the duty on phenol. The Commission investigated comparative foreign and domestic costs and held a public hearing, January 24, 1924, at which Barrett and Bakelite filed briefs opposing the reduction. Analysis revealed that the American cost of production in 1923, including both natural and synthetic phenol, was 142.5 per cent of that of the largest producer of refined phenol in England. Subsequent studies showed a reduction in American costs, and the Commission recommended a decrease in the tariff rates. Accordingly, President Coolidge issued a proclamation, October 31, 1927, decreasing the duty to 20 per cent ad valorem plus 3½ cents a pound, the maximum permissible under the Tariff Act.<sup>44</sup> S. P. Miller, superintendent of the Frankford works of Barrett, testified at the hearing, and Lawrence V. Redman, who appeared for Bakelite, revealed that his company was producing synthetic phenol at the rate of 4,000,000 pounds a year and contemplated increasing this within the next ten months to 7,000,000 pounds. He estimated the 1923 domestic consumption at about 11,000,000 pounds. Five years later, when Bakelite closed down its Painesville plant, it was producing phenol at the rate of some 20,000,000 pounds yearly.<sup>45</sup>

\* U. S. Pat. 1,213,142.

† Holder of over 100 pats., Britton succeeded Hale as dir. org. res. of Dow. He came in 1920 from U. Mich., where he was instructor after receiving his Ph.D. in 1918. Besides the chlorobenzene phenol process, Britton has to his credit industrial improvements in the manufacture of substituted phenols, ethylene glycol, ethylene chlorohydrin, acetic acid, insecticides, and fungicides. He has been counselor of the Am. Chem. Soc.; pres. of the Midland Kiwanis Club; and since 1934 on the Midland Bd. Educ.

‡ Est. 1883; mfrs. of such well-known preparations as Campho-Phenique, Rhumal-Sulphur, Platt's Chlorides, Borozone, and Snow's Liniment.

Recovery of natural phenol from coke-oven ammonia liquor, which enjoyed a comfortable price advantage over the synthetic, was also stimulated, and over 57,000 gallons were reported in 1928 from three plants; the following year, 85,000 gallons from four producers.<sup>46</sup> Recovery was by extraction with benzene, followed by treatment with caustic soda.<sup>47</sup> In 1929 an improved process developed by Koppers was perfected and a closed-cycle system using a mixture of steam and inert gas installed in the coke plant of the Hamilton Coke & Iron Co.<sup>48</sup>

Some of the interest in the low-temperature carbonization process at this time was due to the different proportion of the crudes produced. From the International Combustion installation at New Brunswick, New Jersey, it was expected that the tar acids would run about 25 per cent; phenol about 1 per cent; cresols and xylenols about 10 per cent. Commenting on this significant but commercially unsuccessful venture, Jules Bebie \* of Monsanto wrote: <sup>49</sup> "No matter what the type of a future successful low-temperature carbonization process might be . . . it will not be a factor in phenol production in the near future . . . the tendencies are for increased production of phenol, and particularly of crude phenol, but the development is not expected to be a rapid one . . . the bulk of the future phenol requirements . . . will have to be supplied by the manufacturers of synthetic phenol." In support of this conviction the Monsanto Chemical Works in 1929 built a new and larger phenol plant to operate the sulfonation process.<sup>50</sup>

Cresylic acid,† whose principal use had been as a cattledip and disinfectant, but which now began to enter almost interchangeably with phenol in the manufacture of resins, was closely tied to these developments. Like phenol it is a consideration in the low-temperature process which produces a tar relatively adaptable for the economic recovery of these so-called tar-acid oils. Though subjected to different market influences, the two materials had a remarkably similar price history during the twenties. Between September 1920 and April 1922 the price of cresylic acid dropped from \$1.20 per gallon to 50 cents.<sup>51</sup> In a year it advanced to the highest recorded quotation of \$1.30 a gallon, but in October 1925 it was back again to the low of 1922. This violent fluctuation was accounted for by the sudden rise in demand for cresylic acid as a flotation agent and the equally rapid decline when mining practice substituted *o*-toluidine. Behind this erratic, abnormal market situation

\* Louis Veillon, Gaston DuBois, and Bebie were 3 very competent Swiss chemists who joined John Queeny early in the 20th century, each making notable contributions to the successful establishment of Monsanto. Born in 1876 and educated at Zurich Polytech., Veillon, essentially a chem. engr., was production mgr. of the early days. He retired in 1945 and now lives at Ellenbach, near Lake Zurich, and raises thoroughbred Swiss cattle.

† An indefinite mixture of *o*-, *m*-, and *p*-cresol and phenol.

there was a steady, increasing flow of this material into synthetic resins, which jumped the importations of crude cresylic acid from 2,163,600 in 1925 to 5,802,900 pounds the next year.<sup>52</sup>

Since imports from Great Britain were the mainstay of supply, the traditional consumers of cresylic acid, disturbed by these price gyrations, applied to the Tariff Commission for a decrease in the duty of 7 cents a pound plus 40 per cent ad valorem.\* Investigation and hearings brought out a conflicting complexity of facts. Of the six American producers of cresylic acid during 1922 and 1923, four distilled domestic tar acids, while two worked up imported materials, and it was shown that foreign producers so controlled distillation as to be able to export grades that were exempt from duty under the Tariff of 1922.<sup>53</sup> After refining here, this duty-free, imported material competed directly with U.S.P. cresol, that is, better than 90 per cent grade.

When by proclamation, July 20, 1927, President Coolidge decreased the duty on refined cresylic acid to 20 per cent ad valorem upon the American selling price and 3½ cents per pound, it was with an explanation that since there was insufficient raw material in the United States adequately to supply the demand, consumers must rely upon British supplies.<sup>54</sup> This statement called forth protests. Actually this country was then producing so much coal tar that at least half of it was being burned in open-hearth furnaces,† declared *Chemical & Metallurgical Engineering*. Only a tiny fraction of the 150,000,000 gallons available annually was refined to tar acids and other chemical intermediates, not because of the small demand for cresylic acid, but for pitch and other distilled products. Given a balanced demand, the editorial concluded, there was ample tar in the country to supply the needs both for cresylic acid and U.S.P. cresol.

A couple of years later, at hearings on the Tariff Act of 1929, the International Combustion Tar & Chemical Corporation, which had a critical interest in protection for all these coal-tar acids, amplified this chemical reasoning.<sup>55</sup> Both low-and high-boiling acids are present in the tar, and both must be produced. While domestic consumption of the low-boiling acids was increasing rapidly in synthetic resins, plastics, and for electrical insulation, there was no corresponding market for the

\* Original application, May 4, 1923, by the Insecticide & Disinfectant Mfrs. Assoc. and E. R. Squibb & Sons, joined the following Nov. by Parke, Davis & Co., the Upjohn Co., Sharp & Dohme, Frederick Stearns & Co., Eli Lilly & Co., and Wm. S. Merrell Co.

† "Had the petroleum people the vaguest notion of what was going on in the open-hearth steel and coal-tar chemical industries, I think they would have gotten started in the chemical business right at this point. I tried hard enough, but could not even get them to combine in a little experimental work. It was a case of civil engineers running chemical plants; there was no responsibility in saying 'No,' whereas if they had said 'Yes,' they might have scored an error." (J. R. M. Klotz, to author, July 22, 1946.)

higher-boiling types. The company claimed the capacity of its four plants was over 14,000,000 pounds yearly, of which 9,000,000 pounds were high-boiling acids. With four other companies engaged in this production on a large scale, it was pointed out that domestic demands could be fully met, provided a tariff with a graduated duty based on the actual cresol content of the crude material was enacted.

While phenol and its homologs thus held the center of the stage during the twenties, another coal-tar derivative, phthalic anhydride, was rapidly edging into the limelight. The first notable advance was its use in the preparation of anthraquinone. In 1924, when phthalic anhydride output advanced to a new record and the *Census of Dyes* reported only 25 per cent production of anthraquinone from anthracene, the price of phthalic anhydride came down to 18 cents (prewar the imported German material had been 30 cents) and that of aluminum chloride was reduced from 35 to 20 cents. These unrelated commercial events, united through technology, begat noteworthy chemical progress.

Before this time the rounding out of the American dye industry had been hamstrung by a lack of anthraquinone, the intermediate from which alizarin, the indanthrenes, and other important vat colors are prepared. In Germany this key crude was made by the direct oxidation of anthracene. In this country its recovery remained undeveloped.

Plentiful phthalic anhydride from the Gibbs-Conover-Wohl process and cheap aluminum chloride resulting from the researches of McAfee, Jacobson, and Savell, favored the adoption in this country<sup>56</sup> of the Friedel-Crafts condensation of benzene with phthalic anhydride, in the presence of aluminum chloride, over the chromic acid oxidation of anthracene.\* With cheap, plentiful anthraquinone available, American production of vat dyes advanced rapidly. Naturally the production of phthalic anhydride was stimulated. The Selden Company,† which had been in commercial production since 1918, doubled the capacity of its Pittsburgh plant in 1925, and only three years later announced that, due to the new demand for the manufacture of Glyptal resins, it would im-

\* Improved methods of purifying anthracene have been patented by A. O. Jaeger of Selden Co.; U. S. Pats. 1,685,635 (catalysis) and 1,693,713 (furfural). See Jaeger, *Ind. Eng. Chem.* 20, 1330 (1928).

† Though without chemical training or previous experience in the chemical industry, James McCobb Selden was the father of commercial phthalic anhydride in this country. He early recognized the importance of the Gibbs-Conover process and not only acquired shop rights from the Dept. Agr., but also bought the foreign rights. He organized the Selden Co. to carry on this enterprise and despite early discouragements, which included a disastrous fire, persevered till his company, at the time it merged with Cyanamid, was the largest producer of phthalic in the country. He was born in N. Y. City, Oct. 12, 1863, and died in Pittsburgh, Apr. 12, 1932. His son James, Jr., was actively connected with him in the Selden Co. and later with R. W. Greeff & Co., eventually becoming Eastern sales representative of Shell Oil chemicals.



mediately increase its output to a point exceeding the total 1927 production of all manufacturers.<sup>57</sup> Monsanto doubled its phthalic anhydride capacity, August 1918, and immediately undertook an additional 50 per cent increase.<sup>58</sup>

That fall Selden sued National Aniline unsuccessfully in the Federal District Court at Buffalo for infringement of the basic Gibbs-Conover patent (U. S. Pat. 1,285,117) and reissue 15,520. Occasion for this suit was a revision by Congress of the Government employees' patent rights, permitting them to take out patents in their own names in return for a license to the Government for use of the invention.<sup>59</sup> Shortly thereafter, Selden lost two suits of long standing involving catalytic production of phthalic anhydride. In 1929 the U. S. Circuit Court of Appeals confirmed a lower court's decision that the Downs U. S. Patent 1,604,739, assigned to Barrett, had been infringed.<sup>60</sup> The following year, the Federal District Court in St. Louis invalidated a patent \* which Selden claimed was being infringed by Monsanto's phthalic anhydride process.<sup>61</sup> Successful production of phthalic anhydride hinged upon control of the temperature in the reactor and all sorts of devices were tried to carry the catalyst: gold-plated tubes laid criss-cross, pyramided bricks, staggered shelves, perforated trays with steam pipes above and below, the use of mercury in place of steam, and finger tubes which were the basis of the Downs patent.† Having lost the suit on the mercury-boiling converter, Selden tried control by pressure, adding cadmium and lead to raise the boiling pressure to the range of the reaction, but the alloy did not work because the cadmium and lead boiled out. In the end National Aniline used mercury and Monsanto, Selden, and du Pont a sodium nitrite-nitrate combination which was the HTS (high-temperature salt) of du Pont. Barrett made phthalic anhydride at Frankfort in 1920, but after the Allied consolidation all catalytic work was transferred to Buffalo and the time this took enabled both Selden and Monsanto to get under way. National Aniline, however, had not made this intermediate till March 1921, after the passage of the Nolan Act, so to strengthen its position it purchased American rights to the Wohl patent after it had been declared a prior discovery to the Gibbs-Conover patent.

Paralleling this development of cheaper phthalic was the appearance of anthraquinone intermediates, invaluable in vat-dye manufacture. As early as 1924 methylantraquinone, prepared from phthalic anhydride and toluene by the Friedel-Crafts reaction, was offered on the market and in 1927 National Aniline started the commercial production of  $\beta$ -aminoanthraquinone <sup>62</sup> from  $\beta$ -chloroanthraquinone.

\* U. S. Pat. 1,647,317.

† I am indebted to Dr. Downs for a firsthand summary of these early phthalic developments. (W. H.)

Aniline was another intermediate to which American chemists made important technical contributions. Following the demonstration in 1916 that ferrous chloride, not hydrochloric acid, was the catalytic agent in its preparation by the reduction of nitrobenzene, Robert E. Lyons and L. T. Smith of the University of Indiana carried on a series of theoretical studies of sodium chloride and ferric chloride, and pointed the way to the substitution of neutral catalysts for the acid. This led to the interesting contribution \* of Clark W. Davis of du Pont that niter cake could be advantageously substituted for sodium chloride in these reactions. The Grasselli Dyestuff Corporation worked out a similar process,† using small quantities of ammonium and iron sulfides.<sup>63</sup>

The outstanding contribution, however, was an entirely new method for the preparation of aniline from chlorobenzene and aqua ammonia. This was an accomplishment of the brilliant Dow research team, led by Dr. Hale,‡ and it involved not only comprehensive restudy of the reactions, but demanded adoption of novel engineering features when brought into plant production.

Roughly 45 per cent of the aniline production went into dyes and dye intermediates, according to Groggins,<sup>64</sup> and some 12 per cent into textile finishing. The only other considerable consumption was in rubber accelerators, about 30 per cent, a use that declined with the arrival of other types of chemicals to speed the vulcanization process. The paint industry consumed 8 per cent of the output, chiefly in such dry colors as *p*-nitroaniline red.

Two new aniline derivatives offered by Monsanto for the first time were *o*-nitroaniline in 1927 and *o*-chloroaniline in 1929.<sup>65</sup> At the close of the period, dichloroaniline enjoyed a 97 per cent increase in production due to its greater use as a dye intermediate, while there was a sharp decrease in the output of *p*-nitroaniline.<sup>66</sup> One of the smaller companies, the Crown Chemical Corporation of Keyport, New Jersey, was taken over by Calco in 1929.<sup>67</sup> It had specialized in such aniline intermediates as *p*-nitroaniline, *p*-phenylenediamine, *m*-nitro-*p*-toluidine, *p*-aminophenol, and acetanilide. A series of sulfonamides, *p*-toluenesulfonanilide, ethyl-*p*-toluenesulfonamide, and ethyl-*m*-toluenesulfonamide, were introduced by Monsanto under the trade name of "Santicizers."<sup>68</sup>

Naphthalene was another coal-tar crude that confounded the gloomy prophets. Threatened ruinous overproduction failed to materialize, thanks to scaled-down production from 54 to 39 million pounds, 1923

\* U. S. Pat. 1,663,476 (1928).

† P. Herold and P. Koppe, U. S. Pat. 1,662,421 (1928).

‡ U. S. Pats. 1,607,824 (1926); 1,726,170-1, reiss. 17,280 (1929); 1,764,869, 1,775,360 (1930); 1,804,466, 1,823,025-6 (1931); 1,840,760, 1,885,625 (1932); 1,932,518 (1933); all appl. for between 1926 and 1929, and all ass. to Dow. For Dr. Hale's account of this research project, see Appendix XXXVI.

to 1929, and its new use in the preparation of phthalic anhydride after 1923. The first Southern refiner appeared in 1923, with the organization of the Naphthalene Products Company at Birmingham, incorporated for \$100,000,<sup>69</sup> and other new firms reporting production were the H. F. Watson Company, 1926, Kentucky Color & Chemical Company, 1927, and the Allied Tar & Chemical Corporation, 1928. The use of naphthalene as an intermediate in the production of azo and naphthol dyes increased.<sup>70</sup> A process for removing naphthalene from coke-oven gases, which had been the cause of troublesome gas-line stoppages, was developed in 1924 by the Koppers Company,<sup>71</sup> which in 1929 took over one of the most important units in the naphthalene business, the White Tar Company.<sup>72</sup> Organized in 1909 by Byrd Walker,\* White Tar had started refining naphthalene at Kearney, New Jersey, later branching out into candles and phenol disinfectants to take up the seasonal slack and finally, after acquisition by Koppers' subsidiary American Tar Products Company, going into cresol, *p*-dichlorobenzene, and other coal-tar products.

A valuable addition to the little squad of synthetic, wax-like materials was chlorinated naphthalene, for which Sandford Brown † worked out a commercial process.‡ These products were trade-named Halowax, and the Bakelite Corporation capitalized a wholly owned subsidiary for \$100,000 to exploit them commercially.<sup>72</sup> A plant was built at Wyandotte, Michigan, adjacent to the electrolytic alkali operation of the Pennsylvania Salt Manufacturing Company, and an old Condensite operating man, Orson L. Mauritho, was installed as plant manager with Dr. Ernest R. Hanson as chief chemical engineer.<sup>73</sup>

During 1925-26, Dr. Herbert H. Dow carried on some experiments that proved the possibility of using diphenyloxide vapor in connection with steam for power production.<sup>74</sup> In November 1927, a petroleum refiner asked Theodore Swann of the Federal Phosphorus Company whether he could supply diphenyl in large commercial quantities for use as an indirect heating medium for refining lubricating oils. In

\* Like E. C. Klipstein and E. C. Speiden, Walker came from the town of Marshall, Va., and after 2 yrs. with the local druggist, came to N. Y. in 1885 as salesman for A. Klipstein & Co. He headed White Tar till his death in 1933, when he was followed as gen. mgr. by Herbert W. Hamilton, a Mass. Inst. Tech. graduate who had joined the co. as chem., 1919. Hamilton has been active in the Insecticide & Disinfectant Mfrs. Assoc., serving as vice-pres., 1924-28, and pres., 1928-29.

† A son of Kirk Brown, founder of Condensite, and brother of Allan and Gordon, who with him joined Bakelite after the consolidation. "Sandy" Brown became vice-pres. in 1928, and has been pres. of its subsidiary, Halowax, since its organization in 1923. He was born in Phila., 1889, educated at Cornell and U. Pa., and has made other inventions in processes and equipment.

‡ U. S. Pat. 1,672,878 (1928).

response a process was devised,\* a plant designed and put into operation, and a carload produced, all within four months. Thirty days later this initial unit was dismantled and a second constructed on a new principle which turned out diphenyl at the rate of 3,000 pounds per day.<sup>75</sup> Six months before this rare chemical sold at \$40 a pound; Federal Phosphorus now offered it at 40 cents. Within two years a further reduction of 25 per cent lowered the price to 30 cents. This sensational commercialization opened two paths of development: as a heat-transfer agent and as a chemical reagent.

After inquiring among other chemical manufacturers, a comprehensive research and development program was mapped, and by the close of 1929, 46 different derivatives had been developed. Among these were the *o*- and *p*-chloro-, the nitro- and aminodiphenyls. The most interesting of these were the chlorinated products, ranging from mobile, oily liquids to fine, white crystals and hard, transparent resins. This series was commercialized as Arochlors, which have found many uses as plasticizers for synthetic resins and chlorinated and hard rubbers, as vehicles for paint pigments, as mold lubricants in plastics, combined with Halowax as electrical cable coatings, and as fire retardants.<sup>76</sup>

Diphenyl in place of water in steam boilers makes possible a temperature of 750° F. at but 115 pounds pressure, a characteristic which with its exceptional stability under boiler operation conditions, opened up an entirely new field.<sup>77</sup> Eventually a mixture of diphenyl and diphenyl-oxide proved most economical and efficient and the combination came to be known as Dowtherm.<sup>78</sup>

Attention was drawn at this time to the electrolytic production of intermediates, a number of which were discussed at the fifty-sixth meeting of the American Electrochemical Society in 1929,<sup>79</sup> and in the case of *p*-aminophenol, commercial production was actually reached. Consumption of this intermediate amounted to 160,000 pounds a year, due to its growing use as a fur dye and developer for moving picture films. The wide spread between the cost of its initial material, nitrobenzene, at 9 to 10 cents a pound, and that of the finished product, \$1.25 a pound, prompted the Alox Chemical Company † to experiment with the German method employing hollow, porous carbon cathodes, and an average of 70 per cent yield was achieved. Improvements in the process were made ‡ and commercial production started in the plant at Niagara Falls.<sup>80</sup>

Throughout the period producers of coal-tar intermediates were sub-

\* T. J. Scott, Brit. Pat. 312,902 (1928), ass. to Federal Phosphorus; Fr. Pats. 667,840 (1929) and 715,017 (1931).

† Now Alox Corporation, organized 1926 by Wm. H. Clark.

‡ C. J. Thacher, U. S. Pat. 1,501,472 (1924).

jected to a severe boiling-down process, as the annual *Census of Dyes* records. Production increased by some 123,000,000 pounds and the number of intermediates tripled, but the producers dropped from 106 in 1923 to 77 in 1929. These declining numbers represented some failures, but more were due to consolidation of smaller companies into larger units. An exception to this tendency was the formation of the Elko Chemical Company in 1927, with a capital of \$350,000, which bought out the Southern Dyestuffs Company at Nitro, West Virginia. The move was initiated by Clayton O. North and Carl N. Hand\* of the Rubber Service Laboratories, Akron, who had associated with them E. J. Small, Jr., F. A. Seiberling, the rubber man, and W. D. Payne of Charleston, West Virginia. The manufacture of phenol at the Nitro plant was continued, but instead of producing dyes, the products of the new company included *o*- and *p*-chlorophenol, *p*-aminochlorophenol, di- and trichlorophenol, sulfuryl and thionyl chloride, phosphorus oxychloride, and sodium sulfite.<sup>81</sup>

The Booming Twenties were years of strenuous progress. A reasonably complete line of American-made intermediates necessary for the dye and pharmaceutical industries was rounded out, and substantial, technical progress was made. American coal-tar technology was standing on its own feet, striding forth into new fields.

#### REFERENCES

1. C. J. Ramsburg, *Chem. Ind.* 43, 135 (1938).
2. Co. memo to author.
3. J. M. Weiss, *Chem. Mkts.* 20, 699 (1927); *Ibid.*, memo to author, July 19, 1946.
4. *Chem. Met. Eng.* 34, 469 (1927).
5. Ramsburg, *op. cit.*
6. R. S. McBride, *Chem. Met. Eng.* 36, 359 (1929).
7. Co. memo to author.
8. *Ibid.*
9. *Ibid.*; *Chem. Mkts.* 20, 55 (1927); *O.P.D. Reprtr.* 38A (Jan. 17, 1927); *Chem. Met. Eng.* 34, 127 (1927).
10. *Chem. Mkts.* 20, 55 (1927); 26, 138 (1930).
11. Co. memo to author.
12. *Drug Chem. Mkts.* 10, 511 (1922).
13. Co. memo to author.
14. *Ibid.*; *Ind. Eng. Chem., News Ed.* 9, 51 (1931); *Chem. Met. Eng.* 39, 169 (1932); *O.P.D. Reprtr.* 24 (Feb. 13, 1933).
15. *O.P.D. Reprtr.* 68 (Feb. 16, 1925); *Drug Chem. Mkts.* 16, 264, 417, 721 (1925).
16. *Chem. Mkts.* 21, 442 (1927); 24, 65, 162 (1929).
17. *Ibid.* 26, 65 (1930).
18. W. H. Fulweiler, *Ind. Eng. Chem.* 18, 946 (1926).
19. Co. memo to author.
20. *Ibid.*
21. *Ibid.*

\* North (1891-1936), a Pennsylvanian, educated at Carnegie Inst. Tech., had a thoroughgoing rubber experience with Republic Rubber (1914-16) and Goodyear (1916-21), and before joining Hand in organizing the Rubber Service Labs., held several patents for rubber compounding. He was a Maj. in the Chem. Warfare Reserve. Hand, born 1892, was an enthusiastic booster of the chemical community of Nitro, and was pres., Kanawha Valley Water Co. and Kanawha Valley Nurseries, and dir., Manufacturers' Bank at Nitro. He was educated at Hobart and Mass. Inst. Tech.

22. *Chem. Met. Eng.* 34, 190 (1927).
23. Co. memo to author.
24. *Ibid.*
25. *Chem. Mkts.* 21, 1 (1927).
26. *Chem. Met. Eng.* 34, 656 (1927).
27. *Chem. Mkts.* 20, 489, 510, 806 (1927).
28. *Ibid.* 364.
29. D. W. Jayne, *Chem. Age (London)* 9, 369 (1923); W. Haynes, *Chem. Mkts.* 28, 487 (1931); *Drug Chem. Mkts.* 26, 335 (1924).
30. Weiss, *op. cit.*
31. *Ind. Eng. Chem., News Ed.* 3 (Feb. 10, 1923).
32. *Chem. Met. Eng.* 34, 527, 783 (1927); *Chem. Mkts.* 21, 272 (1927).
33. O.P.D. Repr. 91 (July 9, 1923); *Drug Chem. Mkts.* 13, 537 (1923).
34. Tariff Comm., *Report on Phenol*, 1928; *Chem. Met. Eng.* 28, 825 (1923); Haynes, *op. cit.*; Weiss, *Chem. Ind.* 46, 690 (1940).
35. Tariff Comm., *Report on Phenol*, 1928, p. 3.
36. *Drug Chem. Mkts.* 12, 1493 (1923).
37. Co. memo to author.
38. Tariff Comm., *Report on Phenol*, p. 3.
39. O.P.D. Repr. 36 (Apr. 30, 1923); *Drug Chem. Mkts.* 12, 1039 (1923); *Ind. Eng. Chem.* 28, 784 (1923).
40. Haynes, *op. cit.*
41. *Drug Chem. Mkts.* 16, 1019 (1925).
42. D. H. Killeffer, *Ind. Eng. Chem.* 18, 1044 (1926); W. J. Hale and E. C. Britton, *ibid.* 20, 114 (1928).
43. Hale, to author, July 25, 1946; H. H. Dow, *Mech. Eng.* 48, 815 (1926).
44. Tariff Comm., *Report on Phenol*, 1928; *Census of Dyes*, 1927, p. 23; O. Wilson, *Ind. Eng. Chem.* 19, 918 (1927); *ibid.* 1333; *Chem. Mkts.* 21, 571, 597 (1927).
45. S. Brown, to author, Aug. 1, 1946; *Drug Chem. Mkts.* 14, 323 (1924).
46. Tariff Comm., *Census of Dyes*, 1928, p. 18; 1929, p. 19.
47. F. Talbot and W. N. Watson, *Ind. Eng. Chem.* 21, 8 (1929).
48. B. F. Hatch, *ibid.* 431; Co. memo to author.
49. *Chem. Met. Eng.* 37, 475 (1930).
50. Co. memo to author.
51. Tariff Comm., *Census of Dyes*, 1925, p. 24; *Drug Chem. Mkts.* 18, 619 (1926).
52. Wilson, *op. cit.*
53. Tariff Comm., *Report on Cresylic Acid*, 1927; *ibid.*, *Census of Dyes*, 1927, p. 25.
54. *Chem. Met. Eng.* 34, 469, 514 (1927); *Chem. Mkts.* 20, 977 (1927), 21, 142 (1927).
55. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929, Sched. 1, June 14-18, p. 158.
56. M. Phillips, *Chem. Met. Eng.* 33, 173 (1926); P. H. Groggins, *Chem. Mkts.* 26, 479 (1930); see also C. R. Downs, *Ind. Eng. Chem.* 32, 1294 (1940); C. Conover, *ibid.* 1298; *ibid.* 20, 1283 (1928); Tariff Comm., *Census of Dyes*, 1929, p. 26.
57. *Drug Chem. Mkts.* 16, 1181 (1926); *Chem. Mkts.* 21, 65 (1927), 23, 275 (1928); *Poor's Manual of Industrials*, 1930, p. 1388.
58. Co. memo to author; *Chem. Mkts.* 23, 274 (1928).
59. *Chem. Mkts.* 23, 276 (1928).
60. *Ibid.* 27, 161 (1930); *Chem. Met. Eng.* 36, 177 (1929).
61. *Chem. Mkts.* 26, 397 (1930).
62. Tariff Comm., *Census of Dyes*, 1924, p. 27; Co. memo to author.
63. Groggins, *Chem. Mkts.* 24, 602 (1929); see also his *Aniline and Its Derivatives*, pp. 309, 310, 346.
64. *Ibid.*; *Chem. Mkts.* 24, 602 (1929).
65. *Chem. Mkts.* 21, 125 (1927); O.P.D. Repr. 54 (Apr. 22, 1929).
66. Tariff Comm., *Census of Dyes*, 1930, p. 24; 1926, p. 24.
67. *Chem. Mkts.* 24, 629 (1929).
68. *Ibid.* 23, 275 (1928).
69. *Drug Chem. Mkts.* 12, 1045 (1923).
70. W. B. Nelson, *Am. Dyestuff Repr.* 13, 485 (1924).
71. Co. memo to author.
72. *Ibid.*
73. Haynes, *Chem. Ind.* 37, 334 (1935).
74. *Chem. Met. Eng.* 33, 475 (1926); orig., Dow, *op. cit.*
75. *Chem. Met. Eng.* 36, 329 (1929), 37, 298 (1930); C. H. Penning, *J. Chem. Educ.* 7, 2373 (1930); J. B. Austin and I. A. Black, *J. Am. Chem. Soc.* 52, 4552 (1930).
76. R. L. Jenkins, R. McCullough, and C. F. Booth, *Ind. Eng. Chem.* 22, 31 (1930); L. M. Aycock, *ibid.* 432; Penning, *ibid.* 1180.
77. *Chem. Mkts.* 24, 185 (1929); W. L. Badger, C. C. Monrad, and H. W.

- Diamond, *Ind. Eng. Chem.* 22, 700 (1930).
78. Hale, to author, July 26, 1946.
79. *Chem. Met. Eng.* 36, 602 (1929); orig., *Trans. Am. Electrochem. Soc.* 56, 421-514 (1929).
80. D. Caesar, *Trans. Am. Electrochem. Soc.* 52, 96 (1927); A. W. Burwell, *ibid.* 107; Tariff Comm., *Census of Dyes*, 1927, p. 24.
81. *O.P.D. Repr.* 62 (Oct. 3, 1927); *Chem. Mkts.* 21, 269, 423 (1927).

## Chapter 14

### AMERICAN DYES BUILD A FIRM BASE

KEEN COMPETITION FORCES REVISION OF PROCESSES AND DEVELOPMENT OF NEW COLORS; ENCOURAGES MERGERS—SMALLER MAKERS SPECIALIZE—I.G. SALES CONCENTRATED IN GENERAL DYESTUFF, PRODUCTION IN GENERAL ANILINE—DEALERS REORGANIZE—STANDARDS DEVELOPED BY COLOR LABORATORY—IMPORTS ASSESSED ON STRENGTH—CHEMICAL FOUNDATION AGAIN VINDICATED IN COURT.

**E**NTRENCHED SNUGLY behind the highest United States tariff rates on dyes ever written, American dyemakers—so many feared—would batten contently upon copious profits. Nor was it only sincere free-trade advocates who mistrusted the effects of freedom from foreign competition upon this lusty infant industry. Its customers in the textile, paper, and leather industries knew only too well that there were gaping blanks in the list of made-in-America dyes and that some of those which could be bought left much to be desired in uniformity and quality. They shuddered at the thought of paying fancy prices for unsatisfactory colors and broke into a cold sweat at the mere suggestion of what an advantage this might present to their foreign competitors. Even some chemical men expected that under the benign influence of such very adequate tariff protection, their dyemaking colleagues would wax fat and lazy.

Far from slipping into stagnation, the American dye industry leaped into a melee of competition. The twenties turned out to be a bitter testing period, quite different from the breathless race of the war years, but no less difficult. Competition was keen in the laboratories, the plants, the sales offices. It was that perilous triple-threat competition, distinctive of chemical manufacture, in which revised processes, new products, and lower costs take turns in setting the pace of progress.

Despite the high tariff, or more accurately because it shielded him from foreign competition that would have been avowedly destructive, each American maker went all out to establish his own business upon a permanent basis. Confident of ultimate survival, provided only he could meet American conditions, he worked manfully to correct the shortcomings as well known to him as to his customers.

Most of the cheaper, more easily synthesized bulk dyes had been produced far in excess of normal requirements during the war. This



intensified competition: yield and quality became determining factors of success or failure. The hasty improvisations of the wartime scramble had to be brought up to date. Dyes hitherto unavailable were the magic formula opening the purchasing agent's door, and the more difficult they were to prepare and standardize, and the more attractive their characteristics, the greater the competitive advantage.

Few dyestuff-operating men who struggled through that transition period forgot it, and one of them, Ivan Gubelmann, has given us a terse description:<sup>1</sup> "Until 1926 many of the dyestuff-producing plants operated either at a loss or with very little profit. It was a period of tearing down, of building up again, and of spending large sums of money for research. Yields, operating technic, and chemical apparatus were improved step by step, which resulted in great economies, as indicated by the continued drop of prices for intermediates and finished products. New products were added in great numbers, among them many new fast-to-light direct azo colors and the vat dyes of the thioindigo group. We were moving gradually closer to the ideal of establishing a self-contained American dyestuff industry; this period of 1921-26 was the most constructive in its history."

The financial strain was severe and another du Pont man, Charles M. A. Stine,\* in his Perkin medal acceptance address, has vividly described it:<sup>2</sup> "Without an unwavering faith in research, the organic chemical industry would not exist today. A clear vision of the possibilities of such an industry was also essential, and likewise 'patient money,' as the late John E. Teeple so aptly expressed it. I cannot speak for the entire industry, but I do know that during the early years when the du Pont Company was conducting intensive work with dyestuffs and other organic chemicals, an outlay of more than \$40,000,000 was made without one cent of profit being realized. This outlay represented plant investments, operating losses, and research expenditures. I am sure our experience was not unique."

These statements gave real meaning to the stark statistics of those venturesome years. Between 1923 and 1929 domestic sales of dyes jumped from 86,567,446 to 106,070,887 pounds, while the sales value declined from \$47,223,161 to \$45,842,130: 19,503,441 more pounds sold

\* Vice-pres., dir., and member of the exec. comm. since 1930, Dr. Stine, in addition to conspicuous executive leadership, holds many patents on dyes and intermediates, explosives and detonators, paints and lacquers, resins and solvents. Born in Norwich, Conn., Oct. 18, 1882, he attended Gettysburg (A.B., 1901; B.S., 1903; A.M., 1904; M.S., 1906; hon. D.Sc., 1927) and Johns Hopkins (Ph.D., 1907). In 1907 he went to the du Pont Eastern Lab. in charge of org. research; in 1917 he became head of the Org. Div. of the Chem. Dept.; in 1919, asst. dir. of the Dept.; in 1924, dir. He won the Perkin medal in 1940 and holds hon. degrees from Cumberland and Temple. He has been councilor-at-large of the Am. Chem. Soc.; trustee of Gettysburg Coll., Tower Hill Sch., and Acad. Natural Sci., Phila.; pres., Delaware Hosp., Wilmington.

for 1,381,031 less dollars. During these same years the number of dyes offered the trade doubled.\* That, in a nutshell, is the story of the American dyes during the Booming Twenties.

In this uncompromising struggle for survival weaklings and misfits were grimly rooted out. Casualties were mostly among the smaller firms. But any company which had tangible assets in processes or apparatus or personnel was apt to be absorbed by one of its stronger competitors. The larger makers that were financially strong, and which engaged in extensive research and offered a long list of colors, were importantly strengthened by this concentration process.

It is notable that some exceptionally capable small companies, producing specialty dyes, bucked this trend and prospered, illustrating again the peculiar opportunities before the independent chemical manufacturer of modest means, and contrariwise, showing the extreme difficulty of establishing a monopolistic control of this highly diversified industry where technical expertness and specialized commercial knowledge are so important to success. The triumphs of the larger companies are well remembered: it is not so easy to keep in mind the contributions of the smaller makers. Much first-class technical progress originated in these establishments and they filled many of the gaps in the line of made-in-America colors. From modest beginnings the Pharma-Chemical Corporation and Young Aniline Works have grown to million-dollar investments, and the Peerless Color Company to at least half as much. What Holland and Marietta did in basic dyes and what Atlantic Dye-stuff, Tower, Industrial Dyestuff, and Cooks Falls did in sulfur colors were important in building American production. Webb Hyde's Essex Aniline Works which made chrysophenine, Fred Bacon's little plant at Northboro, Massachusetts, which made safranine, Eric Greene's production of fast red and Philip French's chrome blue black R, all had direct influence upon the development of the industry. The Chemical Manufacturing Company led by Carl P. Waldinger and Thomas O'Neil, the Arnold, Hoffman dye plant at Dighton, Massachusetts, under the manufacturing genius of Thomas Roberts, and the Chemical Company of America, backed by Dr. Samuel Isermann and run by John W. Orelup, were all pioneers.<sup>3</sup>

During these trying years the number of makers of the big-tonnage dyes declined sharply, but there was a definite increase in the number of producers of the dyes made in quantities of less than 75,000 pounds.<sup>4</sup> As a specific instance of this trend, during the crucial years of 1920 to 1925, the makers of 15,000,000-odd pounds of sulfur black were thinned from 12 to 5, while those producing direct brown 3GO (623,757 pounds, 1920) grew from 5 to 13.

\* For detailed figures, see Appendix XXXIV.

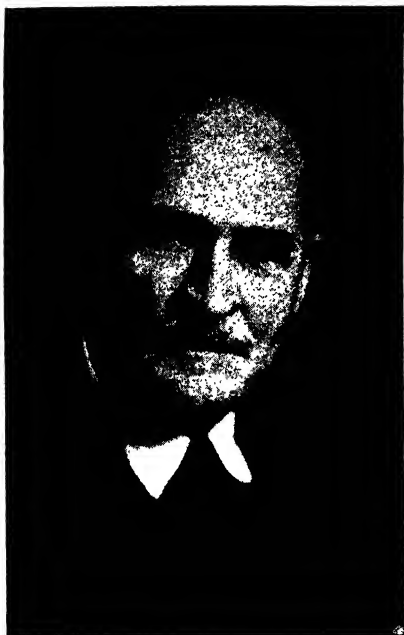
Terrific pressure was being exerted to reduce costs and increase yields,\* as evidenced by the astonishing decline in the average price per pound of all dyestuffs sold from \$1.08 in 1920 to 47 cents in 1925. With the larger companies, all striving to round out their line of dyes, a color produced exclusively by one maker was a considerable competitive advantage. While the force of competition pressed directly upon prices, its most marked effect was a burst of technical progress which greatly strengthened the dye industry in this country. All this was contrary to the pessimistic expectation that the high tariff would hold up prices and strangle technological advance.

Because of the rapid rate of technical progress, mergers and outright purchases, common enough among chemical companies during this period, became in the dye group at once protective and aggressive. To reduce the number of manufacturers, eased the strain by removing "weak" competitors who were the worst price cutters: to increase the number of dyes a company could offer, fortified its position.† Either or both motives prompted many reorganizations and realignments.‡

\* "Often very simple improvements turned failures into success. As an illustration, in the early days we purified  $\alpha$ -naphthol by following the book, dissolving it in caustic soda and filtering. The filtration was arduous; it took 24 hours to filter 300 pounds. Yields were poor, causing some tar formation, and the resultant product was not entirely satisfactory, e.g., for the manufacture of the food color, orange #1. By substituting lime for caustic, 100% yields were obtained and a 300-lb. batch could be filtered in  $\frac{1}{2}$  hr. The product was also clean and free of impurities. In a certain coupling reaction for making one of the dyes, the substitution of ammonia for caustic soda raised the yield from 60% to 95%. Substitution of sodium hypochlorite for potassium chlorate as an oxidizing agent in making one of the basic dyes increased the yield 30%. In the manufacture of one of the vat dyes there resulted a mixture of 50% of the desired product and 50% of an undesirable isomer. To remove this isomer, a problem that was not mentioned in the German patents, a concentrated solution of caustic potash was used. The above serve to illustrate the know-how, not in the patent literature, that was required to make a success in the dyestuff field." (M. Weisberg, to author, Aug. 10, 1946.)

† "I cannot see eye to eye with you on this statement. The last part of the sentence is quite correct, because the trend at this time was to produce everything that the other fellow produced, so that the burden of distribution came directly on the sales force. On the other hand, by reducing the number of manufacturers, the competitive strain was not eased, but on the contrary was sharply intensified. For example, you mention later that Calco bought up a lot of companies. Prior to buying these, it competed in a half-hearted manner against other manufacturers, from whom it obtained dyes in return for Calco-manufactured intermediates, the dyes being returned to Calco on a preferential basis. When, however, Calco bought these other concerns and concentrated the manufacture of the products largely at Bound Brook, it really and truly went to town on a competitive basis and its price competition was tough. It is my opinion that as the regrouping of manufacturers progressed, the competition became much more intense. It is also my belief that in 1927, as a result of these mergers, a great number of colors were selling below their manufacturing cost because of the determination of the larger units of the industry to maintain and increase, if possible, their position as manufacturers and distributors." (A. H. Pierce, to author, July 30, 1946.)

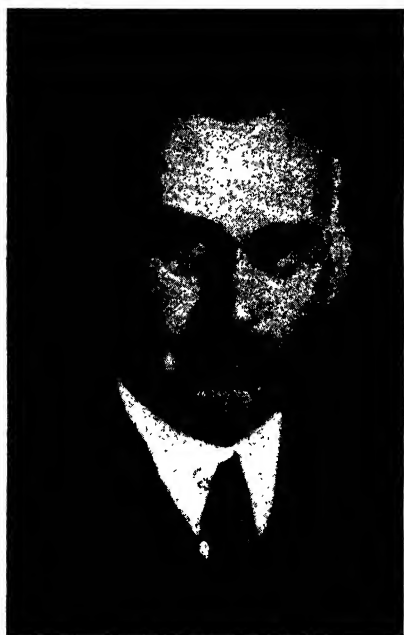
‡ Appendix XXXVII lists the new producers in this field, 1923-29.



FREDERICK G. ZINSSER



ERNEST K. HALBACH



*Chemical & Metallurgical Engineering*  
CHARLES M. A. STINE



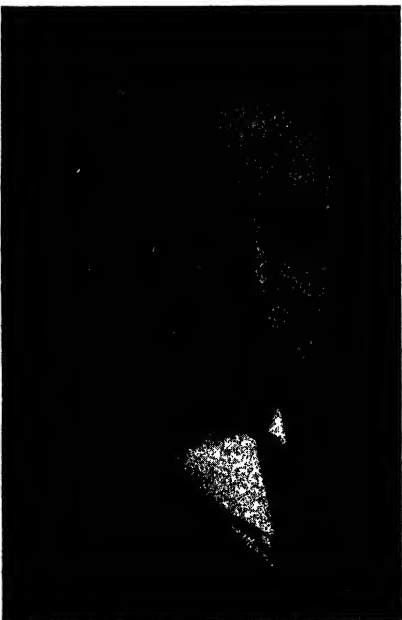
*Oil, Paint & Drug Reporter*  
ALVAH H. PIERCE



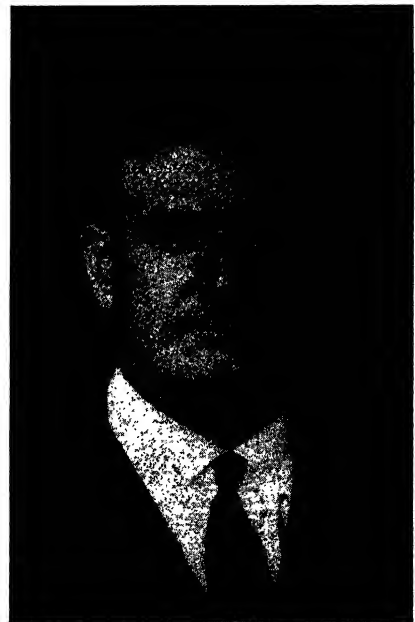
OTTO B. MAY



JOHN W. ORELUP



GEORGE A. GOODELL



SEVIER BONNIE

The Calco Chemical Company, which at first specialized in intermediates, continued to add dyes by buying companies which had previously been its own customers. In 1925 it purchased the Kerin Manufacturing Company of Marietta, Ohio, moving its chief products, auramine, malachite green, brilliant green, and other basic dyes to the home plant at Bound Brook, New Jersey.<sup>5</sup> In 1927 a similar line of dyes, with methylene blue and green and safranine added, were acquired by purchase of the Williamsburg Chemical Company of Brooklyn.<sup>6</sup> During 1929 four such acquisitions were made. The Crown Chemical Corporation \* and the Textile Chemical Company of Providence were bought outright.<sup>7</sup> The latter company, of which Mark Weisberg † was the technical man, manufactured, beside some textile specialties, *a*-naphthol, naphthol yellow S, azo yellow, benzo fast red 8BL, tartrazine, quinoline yellow, and other dyes which Calco continued to make. Calco also took over the Sulfur Dioxide Department of its neighbor, the King Chemical Company, and a line of lake dyestuffs from the May Chemical Works of Dr. Otto B. May, ‡ Newark, New Jersey.<sup>8</sup>

Though itself created by a merger, the National Aniline & Chemical Company added no new dyes by purchase during the twenties, but by 1928 had on the market a line of six vat colors and had substantially extended its Solantine light-fast direct dyes. In 1929 brilliant blue FCF, developed by National chemists as a food color, was officially certified by the Food and Drug Administration.<sup>9</sup> In the meantime manufacturing was being concentrated in Buffalo. In March 1922, the Beckers Brooklyn plant was abandoned and by 1924 all processes and facilities from Marcus Hook had been removed. Thereafter National Aniline's manufacturing operations were consolidated at Buffalo.<sup>10</sup>

During these years the industry fairly hummed with every possible type of reorganization and consolidation. As examples of these shiftings, the Beaver Chemical Corporation, organized <sup>11</sup> in 1923 by the well-known Boston dyestuff man, Charles H. Dunker § of Dunker & Perkins Company, and its plant at Abington, Virginia, were taken over by

\* See Chap. 13.

† A versatile maker of chemical specialties, Weisberg, having been research chem. for New England Mfg. Co. (picric acid), Hercules Powder, Albany Grease Co., Dicks, David Co., and American Vat Color Co., bought the Textile Chemical Co. in 1921. After selling out, he became owner of the Alrose Chemical Co., the Mark Weisberg Labs. which in 1945 became Technic, Inc., and the Bellefont Associates, mfrs. of soluble coffee. Born in Russia, 1890, he graduated from Tufts, B.S. Chem., 1918.

‡ Subsequent to this transfer, Dr. May formed the May Chemical Corp. and Otto B. May, Inc., which engaged in the manufacture of textile dyestuffs. Previous to founding the May Chemical Works in 1917, he had been 10 yrs. with Johann Hoff Co., Newark. He was born in Germany, 1880, and earned his Ph.D. at Strassburg, 1904.

§ Other officers were F. Watson, vice-pres.; John B. Dunbar, treas.; John L. Crist, secy.

A. Klipstein & Company.<sup>12</sup> Dunker moved with his staff to the Klipstein Boston office. Calco took over in 1931 and sent Austin T. Hyde to run the Beaver plant. John L. Crist went to Charlotte as branch sales manager, but shortly afterwards he organized the Southern Dyestuff Corporation.\*

In 1925 the Whitar line of dyes of the White Tar Aniline Corporation was bought by Bachmeier & Company, headed by John H. Bachmeier, an old Kalle man who had branched out for himself in 1916.<sup>13</sup> The following year, another Kalle man, Edward J. Feeley, who had been the German firm's New England manager, organized E. J. Feeley, Inc., and took over the sale of the anthracene colors made by Arnold, Hoffman.<sup>14</sup> The old Brooklyn firm of Ernst Zobel Company, makers of brewer's pitch, printing-ink varnishes, and paints, now managed by the founder's sons, Adolph G. and Ernst L. Zobel, bought into the Textile Chemical Company in Providence,<sup>15</sup> with plans to enlarge the line of dyes which was later purchased by Calco. Another subsequent Calco acquisition, E. C. Klipstein & Sons,† closed down its plants at Chrome and Carteret, New Jersey, and centered manufacturing activities at Charleston, West Virginia.<sup>16</sup> In 1925 the Hord Color Products Company of Sandusky, Ohio, conspicuous among the few wartime dye-making ventures of the Middle West, was sold to R. D. Kehoe of Technical Economists, Inc., New York City, which dismantled and sold the plant unit.<sup>17</sup>

Among the smaller companies there were two important combinations. In 1925, inspired by Dr. Frederick G. Zinsser,‡ Zinsser & Company, § makers of chrome and alizarin dyes, and the Ultro Chemical Corporation, makers of ultramarine and dry colors, united.<sup>18</sup> In 1929 Kentucky Color & Chemical Company of Louisville—George A.

\* Not to be confused with the Nitro, W. Va., Southern Dyestuffs Co. organized by Col. Hobart B. Brown of the Firemen's Insurance Co., Newark, with Carl L. Masters as the operating man. When this was sold, Masters became plant manager of Elko Chemical Co. at Nitro, in 1927. [See *Drug Chem. Mkts.* 10, 79 (1922).]

† When Calco took over, Ernest Klipstein went into Wall St. and his brother Kenneth became mgr., Development Dept., at Bound Brook. Both had been educated at Princeton.

‡ Most distinguished chemical member of a famous scientific family which includes Hans Zinsser, Harvard bacteriologist, author of *Rats, Lice and History*, and William H. and Rudolph Zinsser of the shellac firm of Wm. Zinsser & Co., Fred Zinsser, born in N. Y. City, Mar. 20, 1868, was trained in chem. at Columbia, Louvain, Göttingen, and Heidelberg. In 1891 he became supt. of Wm. Zinsser & Co., and 6 yrs. later estab. Zinsser & Co. at Hastings-on-Hudson, N. Y. Here he served 5 yrs. as pres., Bd. Educ., and 11 yrs. as pres. of the Village. He was Col. in the Chem. Warfare Serv. and pres., Chemists' Club (N.Y.), 1936-37.

§ Other officers were vice-pres. Wm. Steinschneider and Herman T. Staber, who later became respectively secy.-treas. and purchasing agent, and secy.-treas. John S. Zinsser, who went with the Bankers Trust Co. in 1933, to Merck & Co. in 1934, and since 1935 has been pres. of the pharmaceutical house of Sharp & Dohme.

Goodell \* was then general manager—acquired a controlling interest in the National Ultramarine Company, organized in 1923 by U. S. G. Anderson, with a plant at Norwood, Ohio.<sup>19</sup> Anderson, an insurance man, retired and N. B. Conley was named president of the reorganized company, with the Bonnie brothers, Sevier and Robert, of Kentucky Color, vice-president and treasurer respectively, and Joseph F. Pfum remaining as secretary.

Another interesting merger was the Chemical & Dye Corporation, which in 1927 gathered together the Chemical Company of America of Springfield, New Jersey, which had gone into voluntary bankruptcy in 1925, the Tower Company of Newark, New Jersey, and the New England Aniline Works of Ashland, Massachusetts.<sup>20</sup> The Chemical Company of America had been established in 1915 by Samuel Isermann to make intermediates and had produced aniline, benzidine, dimethyl- and diethylaniline, toluidine, nitrotoluene, nitrobenzene, and others, with some dyes of the triphenylmethane series. In 1923 anthraquinones were made and what was claimed to be the first synthetic wetting agent, in 1925. Tower brought sulfur dyes and New England Aniline added wool and direct colors. Headquarters were in Newark and the operation of the Springfield and Ashland plants was placed under the general direction of John W. Orelup,† with the office in charge of the Tower general manager, Hamilton Merrill.

The outstanding dyestuff merger of the twenties was the General Dyestuff Corporation. In 1925 Herman A. Metz organized this corporation which took over Metz' dyestuff interests, the H. A. Metz & Company, American sales agents for Hoechst, and his two manufacturing firms, the Consolidated Color & Chemical Company and the Central Dyestuff & Chemical Company.<sup>21</sup> Simultaneously B. A. Ludwig, formerly vice-president of the National Aniline & Chemical Company and recently appointed sole importer of Cassella dyes, became vice-president of the new corporation and brought with him this sales agency.

The year before, the Grasselli Dyestuff Corporation had been set up with \$4,000,000 capital to take over and operate the dyes end of the Grasselli Chemical Company and to become American selling representative for Bayer dyes.<sup>22</sup> In October 1925, three months after the Hoechst and Cassella interests had been brought into General Dyestuff, the

\* Cofounder of Kentucky Color (1920) and pres. since 1936, Goodell was for 8 yrs. in charge of making dry colors for Sherwin-Williams. A Vermonter educated at Amherst and Columbia, he taught chem. at Columbia and Wellesley, and is coauthor of *Household Chemistry*.

† Born in St. Paul and educated at U. Minn., Orelup had been with Sherwin-Williams, Carus, and Sunbeam before becoming chief chem. of Chemical Co. of America. He later became pres. of Patent Chemicals, Inc.



Grasselli Sales Department and its Bayer agency were taken over, but the plants at Albany and Grasselli remained with the Grasselli Dyestuff Corporation which became purely a manufacturing unit, its products being sold by the new company.<sup>23</sup> At the time of the du Pont-Grasselli merger, several years later, the Grasselli Dyestuff Corporation was sold to the American I.G. Chemical Corporation and became the General Aniline Works. An immediate repercussion to the amalgamation of sales with General Dyestuff was the dropping of Grasselli Dyestuff from the Synthetic Organic Chemical Manufacturers' Association. This action was consistent with the provision that membership be restricted to American manufacturers, but it drew a sharp statement from Dr. Roger N. Wallach, general manager of Grasselli Dyestuff, in which he said that this company had joined the association on special invitation and with full knowledge of its Bayer agency and that prior to combining with General Dyestuff a resignation, which had not been acted upon, had been submitted.<sup>24</sup>

This well-planned amalgamation of the I.G. American importers was completed \* January 1, 1926, when Kuttroff, Pickhardt & Company transferred its exclusive selling agency for Badische dyes and its stocks on hand to the General Dyestuff Corporation.<sup>25</sup> In relinquishing its dyes interests, "K-P" did not go out of business but continued to import and sell German fertilizer specialties, solvents, and other chemicals. General Dyestuff continued the very successful jobbing business it inherited from "K-P" and a substantial part of its turnover was on colors bought from various small American manufacturers. One of the best of these was the Marietta Dyestuffs Company † for which General Dyestuff became exclusive sales agents. A similar selling arrangement was made with the Guyan Color & Chemical Works and a nonexclusive one with the Passaic Color Corporation, Garfield Aniline Works, Beaver Chemical Corporation, and many others.

Official announcement of the final organization was made December 29, but it was three days before it became effective. It surprised no one, and the move was generally interpreted as a concerted effort on the part of the I.G. to rewin American business. The General Dyestuff Corporation was completed just one month after the formal organization

\* "Each of these groups joining General Dyestuff put up a third of the capital, paying in goods or cash, and each divided its third interest among its own people as it saw fit. Kuttroff, Pickhardt billed its physical stock back to Badische and each "K-P" man put up cash to pay for his share of the stock of the new firm. Ludwig, who participated in Metz's third interest, also put up cash." (E. K. Halbach, to author, Aug. 16, 1946.)

† Marietta's history, Appendix XXXVIII, is an example of the development of some of the smaller dyestuff enterprises. In 1926, Graham N. Gleysteen, who had been previously with Sherwin-Williams, became its chief chem. (supt. since 1933). He was born in Ill., 1898, and went to U. Mich., A.B., 1918.

of the I.G. Farbenindustrie.\* It accomplished what Herman Metz had in mind, the formation of a new company in which the three largest importing companies would be combined so that none would get the exclusive agency of the I.G. The numerous duplicating branch offices and warehouses were united at the key textile centers of Boston, Providence, Chicago, Philadelphia, Charlotte, and San Francisco. To amalgamate the personnel was not so simple. Each of the three companies had a full complement of experienced salesmen and trained color technicians. However closely their German principals might have worked together, whatever restraint they may have forced upon their American sales representatives, these firms had been keen rivals. Years of close association had bred loyalty to the old houses and pride in the individual brands. A number of strong, successful, independent personalities were involved. To coalesce these divergent interests and distinctive characters required diplomatic leadership. The task fell to Herman Metz as the first president of General Dyestuff. His surprisingly successful consummation was a final triumph to his tact and leadership.

Adolph Kuttroff, dean of the German dye men, was named chairman of the board. The secretary-general manager was another "K-P" man, Ernest K. Halbach.† From Grasselli came the vice-president and treasurer, Rudolph Hutz, and the technical manager, Herman E. Hager.‡ In charge of sales was B. A. Ludwig and under him another Grasselli-Bayer man, Alvah H. Pierce,§ who in 1926 moved to the important managership of the Boston office. Thus the honors and responsibilities were dealt out to key men representative of the various original companies.

In March 1929, when the Grasselli Dyestuff Corporation was bought and rechristened the General Aniline Works, the I.G. coal-tar chemical manufacturing activities of this country were concentrated in it.<sup>26</sup> Si-

\* Nov. 28, 1925; see Chap. 3.

† An outstanding figure in dye circles, Halbach, born in Phila. and educated in public schools, and the West Chester (Pa.) Teachers Coll., succeeded Metz when he retired as pres. of General Dyestuff. During his regime, besides importing German colors, the company became one of the largest dyemakers in this country. Halbach was largely responsible for the rapid growth of the General Aniline Works, and he handled the imports of I.G. successfully, without raising a question as to his American loyalty.

‡ Vice-pres.-secy. of the affiliated General Aniline Works since 1929 and its pres. in 1935, Hutz was a thoroughgoing Bayer man, born in Elberfeld, Dec. 10, 1877, trained at Jena and Munich and with Bayer since receiving his Ph.D. in 1901. In 1909 he came to U.S. as mgr., Boston office. Hager was also German by birth (1887) and studied at Heidelberg, Munich, and Jena where he won his Ph.D. in 1910. He came to this country as chem. for the Pacific Mills and joined Bayer in 1913.

§ A New Englander, born in Hyde Park, Mass., and educated at Harvard, A.B., 1904, Pierce was asst. mgr. of the Avery Chemical Co., 1908-11; mgr., Boston office of Bayer, 1911-19; asst. sales mgr. at N. Y., 1919; and with Grasselli as sales mgr. of the Dyestuff Dept., 1922-25, till the formation of General Dyestuff.

multaneously with the organization of this new subsidiary, Dr. Carl Bosch, president of the I.G., and several of his directors, arrived in this country with the announced intention of forming a new holding corporation and extending manufacturing operations here. A month later the American I.G. Chemical Corporation was launched with \$60,000,000 assets.<sup>27</sup> With an impressive board of directors, which included Walter Teagle, president of the Standard Oil Company of New Jersey, and Edsel B. Ford, president of the Ford Motor Company, from American industry and such influential financiers as Charles E. Mitchell, chairman, National City Bank of New York, and Paul M. Warburg, chairman, International Acceptance Bank,\* the American I.G. was launched by the sale of \$30,000,000 of 5½ per cent debenture bonds, principal and interest guaranteed by the parent German company, offered by the National City Company. A substantial interest in the American operating subsidiaries, General Aniline and Agfa-Ansco, facilitated the initial financing, but the new company was essentially an investment-management corporation, organized to handle American funds and the sale or lease of American rights to German patents.

Other importing agencies went through similar reorganizations. The year before General Dyestuff was founded, 1924, the Dyestuffs Corporation of America succeeded I. Levinstein & Company and Read, Holliday & Sons Company as sales agents for the dyes made by these British firms.<sup>28</sup> H. R. Davies was the president, and besides selling imported colors, du Pont dyes were handled under a sales arrangement with Levinstein.

Dyes from the three Swiss makers were sold by each manufacturer's American representative: the Ciba Company, the Geigy Company, and the Sandoz Company. This group had bought the dye plant of Ault & Wiborg at Cincinnati† and organized the Cincinnati Chemical Works which with George F. Handel, president, and Dr. E. E. Misslin, head of production and research, began making a line of dyes supplementing the Swiss specialties which the three American sales agents all sold. In addition, Ciba sold the dyes of the Dow Chemical Company.<sup>29</sup> The Swiss firm of Durand & Huguenin was represented by the Carbic Color & Chemical Company, an offshoot of C. Bischoff & Company, established in 1891, which had taken over the founder's interest in 1917 and changed the name in 1921.<sup>30</sup>

More direct control over American sales by foreign manufacturers and efforts of American makers to offer complete lines through their

\* Remaining dir. represented I.G. and its American affiliates: Carl Bosch, I.G.; Adolph Kuttroff; H. A. Metz; W. E. Weiss, vice-pres. of Drug, Inc.; Hermann Schmitz and Wilfrid Greif of exec. comm., I.G.

† See Vol. III, p. 217.

own salesman, compelled the established dyestuff dealers to adjust to these new conditions. Frederick E. Atteaux, prominent in the Boston trade, bought an interest in the Palatine Aniline & Chemical Company of Poughkeepsie, New York, from Matthew Kinneburgh, L. L. Briden, and R. J. Currier.<sup>81</sup> But the sale of this firm's colors was in 1925 transferred to S. R. David & Company,\* which also acted as sales agents for the Guyan Color & Chemical Works and the Standard Ultramarine Company.<sup>82</sup> L. B. Fortner Company, of which Louis Fortner† was president and Alan A. Claflin Boston manager from 1920 to 1932, became sales agents for the Althouse Chemical Company, manufacturers of dyes in Reading, Pennsylvania.<sup>83</sup> One of the old New York dealers, Charles A. Johnson & Company, was reorganized in 1928 as the Hurley-Johnson Corporation, incorporated by T. L. Hurley for \$150,000,<sup>84</sup> originally a partnership from which C. A. Johnson retired in 1920 and was succeeded by J. F. Hurley. Typical of several new local distributors was the New England Chemical Company, incorporated for \$100,000 in Norwich, Connecticut, in 1927, by James F. Quinn, J. G. Quinn, M. T. Quinn, B. Rau, and Z. Greenhalgh.<sup>85</sup>

Amid all these changes progress in dye manufacturing moved steadily forward. Year after year the *Census of Dyes* noted a distinct, continued trend toward dyes of superior fastness and those adapted for special purposes, together with colors of simpler application at lower costs. The number of types increased steadily in spite of the elimination of many items either in small demand or for which better substitutes had become available.

Signal progress was made among the vat dyes which were offered in increasing numbers and of excellent quality by several American makers.<sup>86</sup> The new problem of dyes for cellulose acetate fiber was also solved during this period when in 1924 British Celanese, Ltd., presented a range of 14 new dyes for this color-refractory material, together with novel methods of commercial dyeing.<sup>87</sup> Eighteen of these new SRA dyes were made for the first time in this country in 1925 and 24 offered in 1926,<sup>88</sup> while in the former year Geigy Company‡ introduced a new line of Setacyl colors for acetate silks.<sup>89</sup> Other valuable additions

\* David entered the dye business in 1898 with Bayer and in 1911 was head of the main lab. in N. Y. when he became Beckers' New England mgr. In 1917, when Beckers joined National Aniline, he came to N. Y. as gen. sales mgr., resigning in 1918 to form his own firm.

† Dean of the Phila. color trade, Fortner, who was born in N. Y. state in 1859, started his own business in 1890 after 8 yrs. in the retail drug trade and a similar period as salesman for N. Spencer Thomas Co.

‡ American subsidiary of the famous Swiss house of J. R. Geigy S.A. of Basel, estab. 1764 and makers of dyes since 1859, which had been represented in the U. S. since 1846, first by Fisher & Keller, and after Fisher's death by the surviving partner who incorp. John J. Keller & Co. in 1885. In 1892 Geigy assumed direct control and changed the

to the dye range were the leuco derivatives of indigo named Indigosols; naphthols or stabilized azoic dyes, first made in this country in 1929 by the General Aniline Works; and a new type of oil-soluble azo-resin dyes.<sup>40</sup>

Standards for dyes, most especially reliable measures of fastness, agitated at this time, show the concern with quality. A Color Laboratory was set up in the Department of Agriculture and the Secretary appointed Dr. William J. Hale, who was chairman of the Dye Division of the American Chemical Society, together with R. Norris Shreve, Willard H. Watkins, Dr. Clark G. Derick, and Dr. Louis A. Olney as a special committee to confer with the Bureau of Chemistry in laying out research program, and by frequent consultations to keep the Color Laboratory abreast of industrial needs.<sup>41</sup> The Army had a specific standardization problem in a domestic dye for olive drab that would insure identical dyeing of uniform cloth, and the American Chemical Society appointed a committee of Dr. J. Merritt Matthews, chairman, Professor Olney, and W. I. Joyce of Rhode Island to assist.<sup>42</sup>

A Commission on Standardization of Biological Stains\* to whose financial support the Chemical Foundation contributed, began work in March 1923, investigating methylene blue, basic fuchsin, yellow eosin, and crystal violet, and continuing the search through over 500 distinct dyes used for staining.<sup>43</sup> The Bureau of Standards cooperated with the American Association of Textile Chemists & Colorists on studies of dye fastness to light and washing by spectrophotometric methods, work which was carried on almost continuously since the early 1920's, and the fastness tests published in the A.A.T.C.C. Yearbook, to the great advantage of color maker, user, and ultimate consumer.<sup>44</sup>

Increasingly, the Synthetic Organic Chemical Manufacturers' Association† was serving as a medium for the exchange of thought and reconciliation of conflicting ideas, as well as an instrument of cooperative action among manufacturers of coal-tar products. The organization had had a stormy birth and hazardous youth. Though sharply restricted to firms of unimpeachable American antecedents, its membership included both large makers striving to become self-contained from the production of intermediates to the sale of finished dyes to the consumer, and small producers of specialty dyes who bought their raw materials mostly from their larger competitors and who sold through local dealers. Except at the point of direct competition with imported finished products, these groups seldom stood on common ground. The engage-

name, but Robt. J. Keller, son of John J., became pres. and remained active head till 1928.

\* For history of Comm. and repts., see its publication, *Stain Tech.*, 1926—.

† For officers, 1923-29, see Appendix XLEX.

ment of Dr. Charles H. Herty as president had been a wise move. He was obviously neutral in any conflict of commercial interest and his distinguished name and reputation for probity, his sincere interest in the American chemical industry, his winning personality and wide circle of friends, gave weight and dignity to the organization.

In November 1926, Dr. Herty resigned to become the executive assistant to Francis P. Garvan, president of the Chemical Foundation, and the affairs of the Synthetic Organic Chemical Manufacturers' Association were placed temporarily in the hands of a committee of P. Samuel Rigney, chairman, August Merz, Willis F. Harrington, and Elvin H. Killheffer.<sup>45</sup> The following January Merz was elected president and Charles A. Mace \* was named executive secretary.<sup>46</sup>

The entire dye trade joined in one important, cooperative effort. The 1922 Tariff required sharp distinction between dyes which were competitive and noncompetitive, a technical question based not on its classification in the *Schultz Index*, but on whether the imported dye, on application, produced substantially the same results as a dye made here. To assist appraisers, a committee was appointed of two representatives each from the manufacturers, the importers, and the importing manufacturers, respectively: Dr. E. H. Killheffer and Harrison F. Wilmot;† William P. Pickhardt and Dr. E. O. Patz; Herman A. Metz and Alfred F. Lichtenstein.<sup>47</sup> Collection of the duties under this law involved technicalities and there were hearings and revisions of the rules and court cases.<sup>48</sup> In 1925 the Court of Customs Appeals decided in the famous crystal violet case that imported dyes of strength greater than the standards for imported dyes set up by the Treasury Department were subject to price adjustment upon a strictly competitive basis.<sup>49</sup> To make firsthand contact with the complicated dye situation, the Tariff Commission supplemented its annual questionnaires, upon which was based the *Census of Dyes*, by sending the chief of its Chemical Division, Warren N. Watson, upon field trips to determine the supply and cost of American colors.<sup>50</sup>

This period was also marked by considerable litigation, not confined wholly to the Court of Customs Appeals. Grasselli Dyestuff Corporation entered a suit to protect the Bayer patents which had been acquired by purchase from the Alien Property Custodian. This case against the

\* After the war, Mace, who had been a tech. salesman for Badische (1907-16), chem. for Armour & Co. in By-Products Div. (1903-7), and with Dominion Textiles, Ltd. (1902-3), joined Ciba, 1919-23, and later Butterworth-Judson and Tower Mfg. Co. His knowledge of the dye field, both technical and commercial—he was trained at Mass. Inst. Tech.—his tact and unfailing urbanity have enabled "Charlie" Mace to fill this post with distinction.

† At this time Wilmot (1888-1938) was vice-pres. of S. R. David & Co. He had

L. & R. Organic Products Company involved benzo fast red 8BL, benzo fast Bordeaux 6BL, alizarin rubinol 3G, and diazo brilliant green 3G. It was settled out of court, but it served notice of the determination of the German affiliates to protect what patent rights had been salvaged in the wartime seizure.<sup>51</sup> In 1927 the Supreme Court ended such cases when it ruled that Germans whose property had been seized during the war could not sue individuals or firms, but must look to their Government for redress.<sup>52</sup>

Famous among all the lawsuits of the decade was that of the U. S. Government against the Chemical Foundation, demanding the return of the German patents to the Alien Property Custodian on the grounds that President Wilson had exceeded his authority in sanctioning the sale and that Francis P. Garvan, the Alien Property Custodian, had been negligent of public trust in turning over these patents to the Foundation for a purely nominal sum. The case opened June 3 and closed July 23, 1923, before Judge Hugh M. Morris, Jr., at Wilmington, Delaware.<sup>53</sup> Henry W. Anderson for the Government and William D. Guthrie and Isidor J. Kresel, chief counsels for the defense, called a long, imposing list of witnesses,\* and the taking of testimony consumed 33 days. As the trial progressed, the prosecution was embarrassed by having several of its star witnesses, notably Frank L. Polk, former Under-Secretary of State; A. M. Patterson, president of the Textile Alliance; H. E. Danner, former treasurer of the American Dyes Institute; and George W. McCoy, director of the Hygienic Laboratory, give testimony distinctly favorable to the Foundation.<sup>54</sup>

The proceedings ended in a dramatic climax, a chemical experiment to demonstrate that the specifications of German patents actually revealed the secrets of invention. In support of this contention, Louis Freedman, an employee of the Metz firm who had been called as an expert witness, had testified that while employed by Calco, he had obtained a 60 per cent yield of cinchophen by following the German patent to the letter. Judge Morris requested him to substantiate this claim, by preparing the chemical in the presence of H. D. Gibbs, expert for the Government; M. L. Crossley and E. K. Bolton, experts for the defense; and Gellert Alleman of Swarthmore College, expert representing the court. Dr. Freedman made two batches according to patent specifications. Both were below commercial quality and the yields were 26.9 per cent and 14.3 per cent. The chemist pleaded that he was "put on trial under very severe tests at a very unusual time," referring to his approaching marriage, which drew from the judge the comment that he

attended the Bradford Durfee Textile Sch., and was connected in tech. sales capacities with Kalle, Tinc Tura Lab., and A. Klipstein & Co.

\* For list of witnesses called by both sides, see Appendix XXXIX.

did not consider the test especially severe in view of the assertions made by the witness.<sup>55</sup>

January 3, 1924, Judge Morris handed down a 20,000-word opinion. Its concluding paragraph read: "Finding no ground upon which the sale of enemy property to the defendant may be set aside, the bill of complaint must be dismissed."<sup>56</sup>

Eight months later Attorney General Harlan F. Stone filed a brief in the Philadelphia Circuit Court of Appeals, contending that Judge Morris had erred in his opinion. Again the issue was tried and again President Wilson's executive order for the sale of patents was upheld and the Foundation's officers exonerated of the conspiracy charge.<sup>57</sup>

To close the case beyond peradventure, since any lingering doubt as to the validity of the sale of the patents might involve international complications, the new Attorney General, John G. Sargent, agreed with the Foundation officers and the officials of the Department of Justice to bring it before the Supreme Court.<sup>58</sup> For the third time the sale was vindicated when, on October 11, 1926, the Supreme Court, by unanimous decision, upheld the defendants on every point tested at law, completing finally this famous litigation.<sup>59</sup>

#### REFERENCES

1. *Ind. Eng. Chem.* 27, 619 (1935).
2. *Ibid.* 32, 138 (1940).
3. A. A. Claffin, A. P. Howes, and J. W. Orelup, memos to author. For summaries of this period, see *Textile Colorist*, 50th Anniv. No., 1929; A. P. Sachs, *ibid.* 50, 87 (1928); Repts. on dye symposium, Am. Chem. Soc. meeting, Phila., Sept. 9, 1926, *Ind. Eng. Chem.* 18, 1322-46 (1926); H. E. Fiersz, *J. Soc. Chem. Ind.* 40, R364 (1921); E. H. Killheffer, *Am. Dyestuff Repr.* 18, 594 (1929); B. C. Bond, *ibid.* 22, 491, 503 (1933).
4. *Chem. Mkts.* 20, 361 (1927).
5. O.P.D. Repr. 23 (Feb. 1, 1926); *Drug Chem. Mkts.* 18, 241 (1926).
6. *Chem. Mkts.* 20, 988 (1927).
7. *Ibid.* 24, 629 (1929); 25, 65 (1929).
8. *Ibid.* 25, 181 (1929).
9. Co. memo to author.
10. *Ibid.*; *Drug Chem. Mkts.* 10, 564 (1922).
11. *Ibid.* 12, 1105 (1923).
12. *Chem. Mkts.* 20, 375 (1927).
13. *Drug Chem. Mkts.* 16, 1105 (1925).
14. *Textile Colorist*, 50th Anniv. No., 102 (1929).
15. *Drug Chem. Mkts.* 17, 287 (1925).
16. *Ibid.* 16, 573 (1925).
17. *Ibid.* 1111.
18. *Ibid.* 18, 1242 (1926).
19. *Chem. Mkts.* 25, 71 (1929).
20. Orelup, to author, Oct. 9, 1946; *Textile Colorist* 50, 53 (1928); *Chem. Mkts.* 21, 741 (1927); *Chem. Met. Eng.* 37, 16 (1930).
21. *Ind. Eng. Chem., News Ed.* 7 (July 10, 1925); *Drug Chem. Mkts.* 16, 953 (1925), 17, 15 (1925).
22. *Chem. Met. Eng.* 30, 1035 (1924); *Drug Chem. Mkts.* 14, 1766, 1921 (1924).
23. E. K. Halbach, to author, Aug. 16, 1946; *Drug Chem. Mkts.* 17, 987 (1925); O.P.D. Repr. 21 (Oct. 6, 1925); *Ind. Eng. Chem., News Ed.* 12 (Oct. 20, 1925).
24. O.P.D. Repr. 21 (Nov. 2, 1925); *Drug Chem. Mkts.* 17, 1189 (1925).
25. *Drug Chem. Mkts.* 17, 1803 (1925), Halbach, *op. cit.*
26. *Chem. Mkts.* 24, 293 (1929).
27. *Ibid.* 513; *Tariff Comm., Census of Dyes, 1928*, p. 150.



28. *Textile Colorist*, 50th Anniv. No., 101 (1929).
29. W. J. Hale, to author, July 29, 1946.
30. *Textile Colorist*, 50th Anniv. No., 94.
31. *Drug Chem. Mkts.* 10, 281 (1922).
32. *Textile Colorist*, 50th Anniv. No., 94 (1929).
33. *Drug Chem. Mkts.* 12, 87 (1923).
34. *Chem. Mkts.* 23, 148 (1928).
35. *Ibid.* 20, 248 (1927).
36. D. H. Killeffer, *Ind. Eng. Chem.* 17, 998 (1925); see also annual summaries of new colors in Tariff Comm., *Census of Dyes*, 1923-29.
37. *Drug Chem. Mkts.* 14, 1784 (1924).
38. *Ibid.* 17, 909, 912 (1925); Tariff Comm., *Census of Dyes*, 1925, p. 49, 1926, p. 46.
39. *Textile Colorist*, 50th Anniv. No., 103, 105 (1929).
40. Halbach, *op. cit.*; Tariff Comm., *Census of Dyes*, 1924, p. 55; *Chem. Mkts.* 19, 519 (1926); *Chem. Ind.* 43, 378 (1938); *Color Trade J.* 16, 73 (1925).
41. *Ind. Eng. Chem.* 15, 431, 757 (1923); *Drug Chem. Mkts.* 12, 725 (1923).
42. *Drug Chem. Mkts.* 13, 473 (1923); *Chem. Met. Eng.* 29, 378 (1923).
43. *Ind. Eng. Chem., News Ed.* 4 (Mar. 10, 1923); *Drug. Circ.* 67, 502 (1923).
44. *Chem. Mkts.* 19, 1027 (1926); *Am. Assoc. Textile Chem. Colorists, Yrbk.* 1927, p. 63; see also L. A. Olney, *Am. Dyestuff Reptr.* 35, 574 (1946).
45. *Chem. Mkts.* 19, 1175 (1926).
46. *Ibid.* 1343; 20, 144 (1927).
47. *Drug Chem. Mkts.* 12, 87 (1923).
48. *Ibid.* 14, 331 (1924).
49. *Ibid.* 17, 147 (1925).
50. *Ibid.* 1461.
51. *Ibid.* 1669.
52. *Chem. Mkts.* 20, 552 (1927).
53. *Ind. Eng. Chem.* 15, 664 (1923).
54. *Ibid.* 977.
55. *Ibid.* 884.
56. *Ibid.* 16, 112 (1924); *Ibid., News Ed.* 1 (Jan. 10, 1924); *Chem. Met. Eng.* 30, 28 (1924); *O.P.D. Reptr.* 19 (Jan. 7, 1924); *Drug Chem. Mkts.* 14, 84, 95 (1924).
57. *O.P.D. Reptr.* 61 (Mar. 31, 1924), 19 (Mar. 30, 1925); *Chem. Met. Eng.* 31, 435 (1924); *Drug Chem. Mkts.* 16, 947 (1925); *Ind. Eng. Chem.* 17, 333 (1925); *Pharm. Era* 60, 424 (1925).
58. *Drug Chem. Mkts.* 16, 1250 (1925).
59. *Chem. Mkts.* 19, 939 (1926); *Ind. Eng. Chem.* 18, 1101 (1926); *Drug. Circ.* 70, 878 (1926); *O.P.D. Reptr.* 23 (Oct. 18, 1926).

*PART FOUR*

**MEDICINAL AND OTHER FINE CHEMICALS**



## Chapter 15

### COAL-TAR MEDICINAL CHEMICALS

OFFICIAL RECOGNITION OF SYNTHETIC MEDICINALS—AMERICAN NAMES ADOPTED AS OUTPUTS SOAR—NEW BARBITURATES MARKETED; DUTY BASED ON U.S. SELLING PRICE—RESEARCH IN ARSENICALS, MERCURIALS, NEW ANTISEPTICS: TRYPARSAMIDE, MERCUROCHROME, HEXYLRESORCINOL—UNIVERSITY FELLOWSHIPS SPONSORED BY MANUFACTURERS—FIRMS WITH GERMAN CONNECTIONS REORGANIZE: HEYDEN, LEHN & FINK—DYEMAKERS MAKE MEDICINALS.

LIKE THE COAL-TAR DYES, coal-tar medicinals strengthened their foundations during the twenties. Processes were overhauled and prices brought down from wartime levels. Competition was keen, and while the number of products made in this country increased, the number of manufacturers declined. According to the *Census of Dyes*, there were 58 coal-tar therapeutic agents offered in 1923 and 82 in 1929.\* If there were fewer casualties among the manufacturers—36 firms in 1923 and 30 in 1929—it was not that the battle was fought less fiercely, but that the contestants were fewer, stronger financially, and better equipped technically. Fine chemicals had attracted fewer war speculators and opportunists than the dyes, and there was less fungus growth to be cleaned up.†

Among these coal-tar derivatives there was no great advance in technique comparable to the new processes for phenol and aniline; no new commercial opportunity similar to that offered by the phenolic and alkyd resins. There was, however, substantial progress. The discovery of Mercurochrome, hexylresorcinol, and metaphen, and their manufacture by Hynson, Westcott & Dunning, Sharp & Dohme, and the Abbott Laboratories, respectively, were original, valuable additions to the antiseptics and tangible tokens of the virility of American research and engineering in medicinal chemicals.

Determination to liberate this branch of the industry from German domination was manifest. In many ways this task was more difficult

\* For production figures, see Appendix XXXIV.

† "My impression is there was less attraction because there were fewer of them and less volume demand for each. Certainly during World War I the speculation in manufacture of pharmaceuticals was just as eager but more difficult because of the complicated chemicals involved. The fly-by-night concerns made generally very simple dyes which could be sold regardless of inherent properties because anything colored would sell." (Roger Adams, to author, Sept. 2, 1946.)

to accomplish than in the field of dyes. For excellent, understandable reasons a physician is conservative when prescribing drugs for his patients and he naturally depends heavily upon the reputation of the manufacturers of such therapeutic agents. The German firms had exploited their coal-tar medicinals extensively and expertly. German chemical science was in deservedly high repute and the German characteristic of meticulous concern with detail to assure accuracy was generally credited for the successful manufacture of these complicated fine chemical products. This, plus the adroit sales propaganda couched in scientific language and conducted with ostentatious regard for medical ethics, was bound to impress the American physician. From habit and prompted by caution he continued to prescribe Veronal even when he knew that it was but the German trade name for diethylbarbituric acid. The American layman, ignorant of organic chemistry and susceptible to boldly repeated advertising claims, believed quite implicitly that the only genuine aspirin was stamped with the famous "Bayer cross." If he had heard of acetylsalicylic acid and could pronounce the word, it meant no more to him than did its formula,  $C_9H_8O_4$ .\*

The spirited campaign to establish American synonyms† for the coined German trade names was not jingoistic commercialism, but a serious effort to remove a big stumbling block in the way of American-made coal-tar medicinals. A valid argument for the use of American names was that, while the Government could and did transfer the ownership of enemy-owned patents to the Alien Property Custodian, it could not confiscate trade-mark rights. So if American licensees of German patents on coal-tar medicinals were to manufacture these drugs and sell them under their German names, they would simply be conserving and building up the market for the German brands, establishing these more firmly and making competition increasingly difficult. Recognizing this dilemma, official endorsement was given to distinctive American names for American-made synthetics. The Federal Trade Commission, the National Research Council, and the Council on Pharmacy and Chemistry of the American Medical Association joined in issuing a checklist of the suggested names to replace the foreign terms.<sup>1</sup> Definite help to this cause was rendered by the Federal Trade Commission in 1922, when it charged the Winthrop Chemical Company with false and misleading advertising (for stating that only Veronal made by Winthrop was the genuine product) and after a hearing issued a cease-and-desist order.<sup>2</sup>

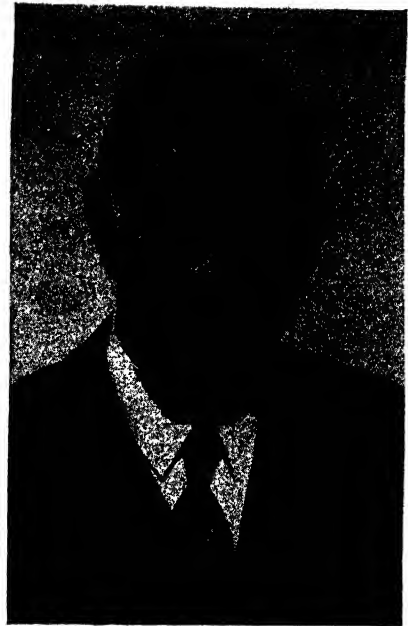
\* See Vol. III, pp. 313-16.

† Aspirin had been ruled by the courts to be an open, generic name, and efforts centered on the use of the words arspenamine for Salvarsan; barbital for Veronal; cinchophen for Atophan; and procaine for Novocaine.



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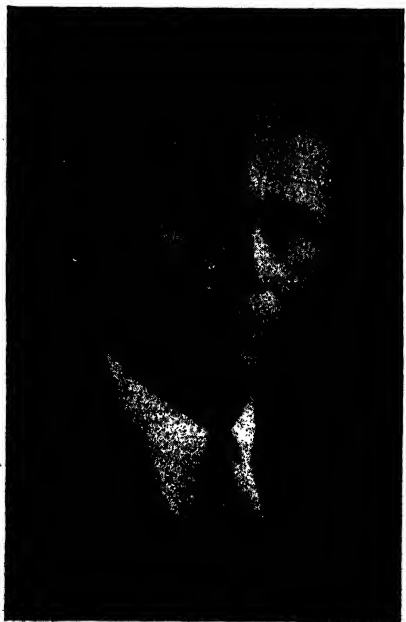
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MORRIS S. KHARASCH



*Chemical & Metallurgical Engineering*  
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*Chemical & Engineering News*  
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GEORGE D. BEAL

On the other side of the ledger, the official prejudice of many medical men against the coal-tar synthetics was rapidly disappearing, and during the twenties these chemicals began notably to replace the barks, roots, leaves, and berries of the ancient *materia medica*. The changes in the tenth edition of the U. S. Pharmacopoeia, which became official January 1, 1926, testified to this new professional attitude. Eleven natural alkaloids were deleted and but a single new one added. Among the synthetic chemicals, however, only three were removed, while seventeen were added, including for the first time such now-familiar products as acetylsalicylic acid, arsphenamine and neoarsphenamine, procaine, barbitol and barbitol-sodium, chloramine-T and dichloramine-T.<sup>3</sup>

Drug addicts among the gangsters and hijackers, and the Government's endless efforts, led at this time by energetic Narcotic Commissioner Nutt, to uproot the underground traffic in habit-forming drugs, kept the so-called drug problem on the first pages of the newspapers. The agitation spurred researches to find harmless synthetic chemical substitutes, and during this decade several new products claimed recognition.

Most of these were barbituric acid derivatives. The Adam of this group is diethylbarbituric acid, discovered in 1903 by Emil Fischer and Josef von Mering; promptly purchased by Bayer; given the trade name Veronal,\* and pushed aggressively in world markets. In this country, soon after the new product was put on the market in 1904, Merck & Co. obtained from Merck of Darmstadt, Germany, a license for manufacturing rights in the United States. Shortly afterwards Bayer established its own subsidiary in this country, Bayer Company, which immediately began to manufacture not only Veronal and aspirin, but other pharmaceutical specialties. During the war Sterling Products acquired Veronal along with the other Bayer medicinals from the Grasselli Chemical Company, which had purchased all the Bayer dye and drug patents from the Alien Property Custodian.

After the war, Sterling Products† separated these synthetic coal-tar chemicals from its proprietary medicine business by setting up two subsidiaries. To preserve every bit of value attached to the association of the name aspirin with the name "Bayer," one of these was named Bayer Company and this specialty allotted to it. Veronal and all the others were placed in the Winthrop Chemical Company. At the time

\* According to the drug trade tradition, this famous trade name was coined by a German pharmaceutical salesman traveling in Italy from the railway station sign, "Verona," but Fischer himself claims a more classical origin, from *verus*, Latin for "true," i.e., the first true synthetic hypnotic. (See *Fortune* 118, Sept. 1934.)

† A holding company for proprietary preparations, controlling such well-known brands as Syrup of Figs, Castoria, Dr. Caldwell's Syrup of Pepsin, Dodson's Livertone, Pape's Diapepsin, Midol, and Phillips' Milk of Magnesia.



the Metz dye interests were amalgamated into the General Dyestuff Corporation, Sterling Products took over the H. A. Metz Laboratories, which had handled medicinal chemicals, and turned over to it some of the drug products allotted to Winthrop.

Since the Sterling Products-Winthrop-Metz supplies of diethylbarbituric acid were drawn from abroad, this arrangement soon left the Abbott Laboratories the sole American manufacturer and in 1922 the Tariff Commission was petitioned to change the basis of this duty from foreign valuation to the American selling price.<sup>4</sup> The customary hearings were held by the Commission beginning March 27, 1923, and November 6 of the year following, a report was submitted to the President recommending this change which he then proclaimed effective as of November 14, 1924. In spite of this advantage, which covered not only diethylbarbituric acid but its salts and compounds, imports increased markedly from 1,221 pounds to 30,874 pounds between 1924 and 1929,<sup>5</sup> an increase due chiefly to the importation of other barbiturates.

Several new barbituric acid derivatives appeared during these years. The first, phenylethylbarbituric acid, was introduced under the trade name Luminal, along with its salt Luminal-Sodium, by Bayer in 1924.<sup>6</sup> On its heels came the first American sedative of this group, Amytal (isoamylethylbarbituric acid), developed by Eli Lilly & Company which put its sodium salt on the market four years later.<sup>7</sup> Abbott Laboratories in 1925 began the manufacture of n-butylethylbarbituric acid, trade-named Neonal,<sup>8</sup> under a license arrangement with Etablissements Poulenc Frères.\* In 1926 another American discovery among this group of sedatives appeared in Ipral, the calcium salt of ethylisopropylbarbituric acid, introduced by E. R. Squibb & Sons,<sup>9</sup> while the following year another foreign compound, Allonal, allylisopropylbarbituric acid, was offered for the first time by the Hoffman-La Roche Chemical Works, American affiliate of the Swiss pharmaceutical house.<sup>10</sup>

It is interesting to note that despite the efforts to identify coal-tar chemical specialties either by an American synonym or by its proper chemical name, Veronal continued to sell at \$4 an ounce as against 60 cents for barbital, and Luminal was priced at \$6.90 with the identical phenobarbital selling for 72 cents an ounce.<sup>11</sup> With such substantial price differentials, it is easy to see why, in spite of a 50 per cent duty on the American selling price, the importation of these specialties continued to be exceedingly profitable.

Ehrlich's discovery of arsphenamine in 1909 had raised high hopes of synthesizing groups of chemicals which would be specifically toxic against disease-causing microorganisms. This glowing expectation of

\* E. Layraud, U. S. Pat. 1,609,520 (1926), ass. to Poulenc Frères.

chemotherapy was not immediately fulfilled. In fact it was 20 years before the sulfa drugs brought mankind the second great weapon against bacterial diseases.<sup>12</sup> Nevertheless, the twenties were not entirely sterile of progress in this direction. Research went on and reasonably effective remedies against African sleeping sickness, syphilis, and other parasitic and bacterial diseases were uncovered.

Ehrlich himself had led the way in the hunt for a cure for the deadly tropical disease carried by the tsetse fly, and in 1920 Bayer announced Germanin,\* better known as Bayer 205, as a specific trypanocide.<sup>13</sup> In 1918 Drs. W. A. Jacobs and M. Heidelberger, working at the Rockefeller Institute for Medical Research in New York City, synthesized an organic arsenic derivative, the sodium salt of *p*-arsono-N<sup>a</sup>-phenylglycinamide,  $C_8H_{10}AsN_2O_4Na$ , which was found to have excellent trypanocidal powers.† It was patented‡ and licenses for its manufacture were granted in 1923 to May & Baker in England, to Etablissements Poulenc Frères in France, and to Powers-Weightman-Rosengarten in the United States. "P-W-R" placed it on the market in 1925 under the coined name tryparsamide.<sup>14</sup> About the same time, working in cooperation with Poulenc Frères, this firm also began the production of arsphenamine, neoarsphenamine, and sulfarsphenamine.

These antisyphilitics were manufactured in this country by a number of companies during the twenties. Throughout the entire period all three were produced by Abbott Laboratories and E. R. Squibb & Sons; Powers-Weightman-Rosengarten, who came into production in 1923, dropped out in 1926 or 1927, while Merck & Co. began manufacturing them in 1927. The H. A. Metz Laboratories, the Diarsenoi Laboratories, the Mallinckrodt Chemical Works, and the Massachusetts Department of Health, all reported their production.<sup>15</sup> Throughout these years neoarsphenamine continued to hold first place, its output more than doubling the combined production of arsphenamine and sulfarsphenamine.<sup>16</sup>

At this time two new medicinals—one American, one German—appeared. Bismarsen, a product of Abbott Laboratories' research, is bismuth arsphenamine sulfonate, § containing approximately 13 per cent of arsenic and 24 per cent of bismuth.<sup>17</sup> Salyrgan, a complex mercurial

\* The German Govt. again attempted to use chemicals as a cat's-paw in economic and political diplomacy when it proposed to exchange this drug, obviously a boon to the development of the Black Continent by white men, in return for the German African colonies lost during World War I. The British reaction to this amazing proposal was distinctly unfriendly and since the French chemist, Fourneau, succeeded in duplicating the synthesis of the complex molecule ( $C_{61}H_{14}O_{22}N_8S_4Na_2$ ) shortly afterwards, the matter was promptly dropped. (See Haynes, *This Chemical Age*, p. 130.)

† See Vol. III, p. 320.

‡ U. S. Pats. 1,280,119-26 (1918).

§ G. W. Raiziss and A. Kremens, U. S. Pat. 1,605,691 (1926), ass. to Abbott.

prepared by the action of mercury acetate and methyl alcohol on salicylallylamido-*o*-acetic acid and subsequent conversion into the sodium salt,<sup>18</sup> was put on the market by the H. A. Metz Laboratories.\* It contains nearly 40 per cent mercury and though exerting some antisypilitic action has been chiefly used as a diuretic.

Recognizing that high toxicity accompanies the high therapeutic activity of arsenicals, the U. S. Public Health Service, acting under the authority of the Act of Congress of 1902, set up standards for the biological testing of arsphenamine and its derivatives. In addition to tests by manufacturers, samples of all lots were submitted to the Hygienic Laboratory and tested biologically. Henceforth the manufacture and sale of these products was made subject to licensing from the Public Health Service.<sup>19</sup> At the same time, to control imports, it was ruled that such products brought into the United States must have been made in an establishment holding a U. S. Treasury Department license and in 1922 such licenses were issued to Hoechst for arsphenamine, neoarsphenamine, sodium arsphenamine, and silver arsphenamine; to Poulenc Frères for arsphenamine and neoarsphenamine; and to the Laboratoires Naline for phospharsphenamine.<sup>20</sup>

Interest in the highly elaborated organic compounds of mercury as bactericidal agents continued keen. One of the first, most famous American discoveries in this field, Mercurochrome, came into great prominence at this time, "sired," as it was said, "by Dunning † and mothered by Johns Hopkins."<sup>21</sup> One of the products of the researches directed by Dr. Ira Remsen, phenolsulfonphthalein, had been tested at the Johns Hopkins' Hospital laboratories by Dr. John J. Abel and found to be a valuable indicator in estimating kidney function. Dr. J. T. Geraghty, who had been using this dye in human beings, suggested to H. A. B. Dunning, the young chemist in charge of research at Hynson, Westcott & Dunning, that if silver or mercury might be combined in this molecule, a valuable genitourinary antiseptic might result. Following this lead, another young chemist, Edwin C. White ‡ of the Brady Clinic at Johns Hopkins, succeeded in introducing mercury into this molecule.<sup>22</sup> Later, Dunning worked out a soluble form, the disodium salt of 2, 7-dibromo-4-hydroxy-mercurifluorescein containing 24-26.7 per cent of mercury, which began its career as an antiseptic under the sponsorship of the distinguished specialist, Dr. Hugh H. Young, also of Johns Hopkins.

\* U. S. Trade-Mark 188,515; no U. S. pat. was taken out on this substance.

† See Vol. III, p. 306.

‡ White earned his A.B. at Johns Hopkins in 1912 and his Ph.D. at U. Wis. in 1915. After 2 yrs. with the Bur. Mines, he has been continuously associated with chemical-bacteriological research at Johns Hopkins U. See also Vol. III, p. 323.

Metaphen, the anhydride of 4-nitro-5-hydroxymercuri-*o*-cresol, a powerful germicide discovered by Dr. George W. Raiziss, was put upon the market in 1924 by the Abbott Laboratories.<sup>23</sup> Shortly after, a third member of this group appeared in phenylmercuric nitrate. This was studied by Dr. Lyle A. Weed of the Iowa State College, who later, in collaboration with Dr. E. E. Ecker of the Western Reserve Medical School, evolved a commercial method for the preparation of this salt and the corresponding chloride.<sup>24</sup> \*

An important addition to the antiseptics was hexylresorcinol, announced in 1925 by Dr. Veador Leonard of the Johns Hopkins School of Hygiene and Public Health and Dr. Treat B. Johnson, professor of organic chemistry at Yale.<sup>25</sup> Some ten years' hunt for chemical compounds akin to phenol had preceded this discovery, which led to an exhaustive study of the resorcinols, climaxed by the discovery of *n*-hexyl-2,4-dihydroxybenzene. It was made and marketed by Sharp & Dohme which, in 1927, sued Boots in England for infringement of a basic patent,† which was invalidated because of this previous art.<sup>26</sup>

Still another organic germicide, the result of several years' research, was put on the market in 1928, by Eli Lilly & Company.<sup>27</sup> This compound, Merthiolate (sodium ethylmercurithiosalicylate), was developed in collaboration with the Lilly staff by Morris S. Kharasch‡ while professor of chemistry at the University of Chicago. An interesting addition to agents for the treatment of burns was butesin picrate—62 per cent butesin (*n*-butyl *p*-aminobenzoate) and 37.4 per cent trinitrophenol—which was evolved in the Abbott Laboratories by Floyd K. Thayer. The year following this discovery, he forsook research work to become manager of the Chemical Sales Department.<sup>28</sup>

In the background of these successful commercial introductions, organic medicinal research activities teemed in many laboratories. In a number of ways these were untried activities for most American chemical companies. They involved not only organic chemistry, but biology and biochemistry, and called for therapeutic tests and clinical proof. The interest of physicians and hospital authorities had to be enlisted and their cooperation organized and coordinated. The National Research Council lent a helpful hand. Its Committee on Chemical Research on Medicinal Substances, headed by Professor Marston T.

\* It was not till 1935 that U. S. Pat. 2,014,676 was granted to Weed, who ass. it to Hamilton Labs.; and 1942 before phenylmercuric compounds were accepted by the Council of Pharm. & Chem. of the Am. Med. Assoc. for inclusion in *New & Non-Official Remedies*.

† A. R. L. Dohme, Brit. Pat. 219,922 (1923).

‡ Born in the Ukraine in 1895 and educated at U. Chicago, Kharasch, after being Nat. Res. Council org. chem. fellow at the Sprague Mem. Inst. for 5 yrs., went to U. Md. as prof. org. chem., 1922-28, then to U. Chicago where he has been ever since.

Bogert,\* had a distinguished membership: Professor Roger Adams of Illinois; Henry V. Army, the College of Pharmacy at Columbia; George D. Beal, distinguished pharmaceutical chemist, assistant director of the Mellon Institute; Arthur W. Dox of Parke, Davis; Frederick W. Heyl of Upjohn; Professors Arthur J. Hill and Treat B. Johnson of Yale; Charles H. LaWall, dean of the Philadelphia College of Pharmacy; R. R. Renshaw, professor of organic chemistry at the Harvard School of Medicine; W. Lee Lewis, director of scientific research for the Institute of American Meat Packers; and Frank C. Whitmore of Northwestern University, soon to become dean of chemistry and physics at Pennsylvania State College. Through these men contacts were established with the workers in company laboratories, medical schools, and hospitals, thus forming an informal, disinterested clearing house for information. This time-consuming task was of inestimable value in forging that friendly coalition of chemistry, pharmacy, and medicine, essential to the most resultful research.

A characteristic sign of the times was the great number of university fellowships for research in medicinal products, established by manufacturers. Leaders in this cooperative work were Columbia, Chicago, and especially Northwestern, where under Frank C. Whitmore,† a dozen fellowships were maintained for study of organic compounds of arsenic and mercury.<sup>29</sup>

Although the manufacture of coal-tar dyes and coal-tar medicinals has usually been carried on by different firms in this country, during the twenties two of the biggest intermediate and dyestuff producers,

\* Bogert, "beloved teacher and esteemed diplomat of chemistry," is said to have held more distinguished public posts and more honorary memberships than any other American chemist. He studied at Columbia and has been identified with that institution since graduation (A.B., 1890; hon. D.Sc., 1929), from asst. org. chem. to prof. (1904), retiring in 1940. He has received the Nichols, Priestley, and Am. Inst. Chem. medals, and those of both the Charles and the Bratislava U., Czechoslovakia, where he was the 1st Carnegie exchange prof. He was Col., Chem. Warfare Serv., 1918-19; organizer of the Chemical Div., Nat. Res. Council; ed., *J. Org. Chem.*; pres., Am. Chem. Soc., Soc. Chem. Ind., Internat. Union Chem., and Chemists' Club (N. Y.). A finished speaker, he is a favorite toastmaster and dispenser of honors, upon which occasions he delights to wear a tie dyed with the original Perkin coal-tar mauve.

† Whitmore, who had recently published his *Organic Compounds of Mercury* (1921) and was serving as chief ed. of *Organic Syntheses* (1925, '27, '32), was proving his ability as liaison officer between industry and education. Born in N. Attleboro, Mass., 1887, he was trained at Harvard (A.B., 1911; A.M., 1912; Ph.D., 1914) and from instructor of org. chem. at Williams he went to Rice Inst., to U. Minn., to Northwestern (prof. org. chem., 1920; head dept., 1925-29), thence to Penn State where he has since been dean. During both World Wars he served in important consulting and production positions. Author of a widely used text on org. chem., Whitmore was assoc. ed., *J. Am. Chem. Soc.*, consulting ed., *Chem. Ind.* (1927-31) and *Encycl. Britannica* (14th ed.). He won the Nichols medal (1937), the Modern Pioneer award (1939), and the Gibbs medal (1945), was pres., Am. Chem. Soc. (1938). He died, June 24, 1947.

National Aniline and Newport, made important excursions into the medicinal field. National Aniline established a department for the manufacture of coal-tar pharmaceuticals and biological dyes in 1921. This new department took over the Heyl Laboratories and George Heyl\* came along to have charge of manufacturing activities, while Lewis H. Marks headed research and sales.<sup>30</sup> Three years later Dr. H. Sheridan Baketel,† who since 1911 had been the medical director of H. A. Metz Laboratories, resigned to become general manager of this pharmaceutical department.<sup>31</sup> The Newport Company entered the fine chemical field in 1929 through purchase of the Rhodia Chemical Company, manufacturers of medicinal, photographic, and other organic chemical specialties.<sup>32</sup> With Rhodia came an association with the French Société des Usines Chimiques Rhône-Poulenc of Paris and A. Sorin & Cie of Grasse, including the sales rights in this country to their pharmaceutical and aromatic specialties.

The Heyden Chemical Company of America became in 1925 the Heyden Chemical Corporation. This was more than a change in corporate name. In 1922 Bernard R. Armour, president of American Aniline Products, Inc., had purchased 500,000 shares of this company from Allan A. Ryan, who had been the successful bidder at the Alien Property Custodian's sale of the Heyden plant and properties.‡ Armour reorganized the corporation, adopting the new name, lowered the capitalization from \$2,500,000 to \$2,000,000, merged with it the Denhey Corporation,§ and named as directors Bernard R. Armour, F. William Weckman, and Sigmund S. Theil.<sup>33</sup> Shortly thereafter Heyden bought the Norvell Chemical Corporation, an offshoot of the old wholesale drug company of McKesson & Robbins.¶ This purchase, which involved \$125,000 cash and 3,000 shares of Heyden preferred stock, brought to the corporation a variety of fine chemicals with sales of

\* One of the first to introduce medicinal and antiseptic dyes in U. S., Geo. F. W. V. Heyl, born in Germany in 1886, remained with National Aniline for 2 yrs. In 1927 he became dir. of development at United Color & Pigment Co., which was taken over by Interchemical Corp. in 1934.

† Baketel became pres. of Reed & Carnrick in 1926. Active leader in many fields, he was born in Ohio, 1872, educated at Phillips Exeter, Boston U., and Dartmouth (M.D., 1895). He was adv. mgr., Denver Chemical Mfg. Co., 1905-10, when he joined the Metz Labs. Besides practicing, he edited several journals and helped found *Med. Economics* in 1923. He saw 33 mos. active service as Maj., U. S. Med. Corps, during World War I. He had been prof. in L. I. Coll. Med. since 1913 and chairman, bd. trustees, Columbia U. Coll. Pharm. He was cofounder of med. frat., Alpha Kappa Kappa; pres., Am. Med. Editors Assoc.; and is a member of many medical and scientific societies.

‡ See Vol. III, p. 324.

§ A corporation utilized only in working out certain legal details in connection with the foreign interests in the American company. [See *Drug Chem. Mkts.* 17, 1254 (1925).]

¶ See Chap. 17.

about \$1,000,000 a year; the Perth Amboy factory site of 71 acres on the Raritan River; plant and equipment appraised at \$605,500;<sup>34</sup> and most important of all, an old Heyden man, then sales manager of Norvell, George W. Simon.\* This experienced, popular executive became vice-president and treasurer and assumed control of sales. Before the war he had been in active charge of the American business of Chemische Fabrik von Heyden; in fact, in 1900 he had incorporated the original Heyden Chemical Works. Simon was not only thoroughly familiar with its products—salicylic acid and derivatives, formaldehyde, saccharin, and various medicinal silver salts—but he was able to reestablish on an amicable basis, contact with the German house whose patents and property had been sold by the Alien Property Custodian.

Another firm with prewar German connections set its house in order during the twenties when Lehn & Fink organized the Lehn & Fink Products Company. The business was originally formed in 1874 as a partnership by Louis Lehn and F. W. Fink, the father of Colin Fink. Prewar, they had the American selling rights to Lysol, a proprietary cresol disinfectant and the tooth paste Pebeco. These products, together with Hinds' Honey & Almond Cream bought from A. S. Hinds Company of Portland, Maine, were all gathered into the new company, operations being centered at the Bloomfield, New Jersey, plant in which Lysol had been made since 1920 and where there was a new research laboratory.<sup>35</sup> Though the new, complex coal-tar antiseptics were making great headway, the phenolic disinfectants continued to hold an important place, and the old firm of Baird & McGuire† manufacturing cresol compounds, insecticides, and other sanitary specialties, added to its plant at Holbrook, Massachusetts, a new one in the Middle West at St. Louis.<sup>36</sup>

Throughout these years of many changes the annual reports of the *Census of Dyes* reveal remarkably few shifts among the principal producers of the large-tonnage items. Aspirin production, the largest of all these, grew from 1,482,998 pounds in 1922 to 2,710,374 in 1929. It was made during these years by Dow, Monsanto, and Bayer. Merck discontinued manufacture of acetylsalicylic acid in 1927, but that year Heyden began it, having previously confined itself to the manufacture

\* Born in Germany, Simon came to U. S. at age of 28 to inc. Heyden Chemical Works. He was very active in the Am. Drug Mfrs. Assoc. prior to his retirement in Apr. 1944.

† Estab. as a partnership in 1914 by Chas. Campbell Baird and Jas. H. McGuire. Baird, a Scotsman born in 1880, has been since 1904 chief chem. of Samuel Cabot, Inc., mfrs. of coal-tar disinfectants, shingle stains, etc. McGuire had been a member of the firm of Knox & Morse, Boston, since 1905. He was born in N. Y. state, 1876, educated at Cornell (B.S., 1898), and was successively chem. with Braeburn Steel, Lowe Bros. Paint Co., Cayuga Lake Cement, and New England Gas & Coke. Since 1933 he has been sales mgr., Jas. Huggins & Sons.

of salicylic acid sold largely to Bayer for conversion to aspirin. Though three—salol, sodium salicylate, and phenolsulfonates—all declined, the output of most of these coal-tar derivatives grew during the period. Acetanilide production, for example, went up from 222,517 pounds in 1922 to 355,019 pounds in 1929, producers through the period being Maywood Chemical Works and the New York Quinine & Chemical Works; other producers in 1923, Powers-Weightman-Rosengarten; in 1923-27, Merck; after 1927, Monsanto. Sensational advances were made by cinchophen (known to the Germans as Atophan) and benzocaine. The former was made throughout the twenties by Calco, Abbott Laboratories, Alyco Manufacturing, and Eli Lilly, and intermittently by Benzol Products and Pfizer, while Dow began production in 1929. Cinchophen output virtually trebled—32 to 99 thousand pounds—though its sales value increased only from \$299,010 to \$407,711. Benzocaine output multiplied most rapidly of all, from 1,658 pounds in 1922 to 6,300 pounds in 1928. It was offered during these years by Abbott, Metz, and two companies specializing in benzoic acid compounds, the Novocol Chemical Manufacturing Company and the Seydel Chemical Company.

At the very end of that eventful decade, the facilities of American manufacturers of these coal-tar medicinals were severely tested by an influenza epidemic which swept the country between November 1928 and March 1929.<sup>37</sup> The scourge struck unexpectedly and spread rapidly, creating an enormous demand for aspirin, acetphenetidine, antipyrine, guaiacol carbonate, acetanilide, and menthol, as well as for a number of other fine chemicals used in the manufacture of popular influenza remedies and prescribed by physicians. Despite this critical demand, which did create some local shortages because of the distribution problems it involved, the market for coal-tar medicinal chemicals remained notably steady and there was no really acute failure in their supply.

#### REFERENCES

1. *Pharm. Era* 58, 164 (1924).
2. *Drug Chem. Mkts.* 10, 334 (1922).
3. *Drug. Circ.* 69, 302 (1925). See also H. V. Arny, *Ind. Eng. Chem.* 18, 949 (1926); R. Adams, *ibid.* 1182.
4. Tariff Comm., *Report on Diethylbarbituric Acid and Derivatives*, 1925; *Ibid.*, *Census of Dyes, 1924*, p. 126; *Drug Chem. Mkts.* 12, 793 (1923); *Drug. Circ.* 52 (Jan. 1924); *Pharm. Era* 59, 498 (1924).
5. *J. Am. Pharm. Assoc.* 17, 1112 (1928); Tariff Comm., *Census of Dyes, 1929*, p. 139.
6. Tariff Comm., *Census of Dyes, 1924*, p. 62; D. H. Killeffer, *Ind. Eng. Chem.* 17, 1021 (1925); *Drug Chem. Mkts.* 14, 1323 (1924).
7. Co. memo to author; Tariff Comm., *Census of Dyes, 1924*, p. 123; Killeffer, *op. cit.*
8. E. H. Volwiler, to author, Oct. 31, 1946; see also C. Nielsen, J. A. Higgins,



- and H. C. Spruth, *J. Pharmacol.* 26, 371 (1925).
9. *Am. Druggist* 49 (Apr. 1926).
  10. *Drug. Circ.* 71, 182 (1927).
  11. *Fortune* 118 (Sept. 1934).
  12. Haynes, *Chemical Front*, p. 106.
  13. *Chem. Met. Eng.* 30, 129 (1924); *Drug Chem. Mkts.* 14, 474 (1924); *Am. Druggist* 17 (Jan. 1925); A. Balfour, League of Nations, Internat. Econ. Conf., *Chemical Industry*, 79 (1927).
  14. A. G. Rosengarten, to author, 1944; *Chem. Mkts.* 20, 709 (1927).
  15. Tariff Comm., *Census of Dyes, 1923-29*.
  16. *Ibid.*
  17. *J. Am. Pharm. Assoc.* 18, 1215 (1929).
  18. *Ibid.* 526.
  19. H. B. Corbitt, *ibid.* 12, 620 (1923); C. Voegtlin, *Physiol. Rev.* 5, 63 (1925).
  20. *Drug Chem. Mkts.* 10, 569 (1922).
  21. *Am. Druggist* 33 (June 1926).
  22. *Pharm. Era* 58, 458 (1924); *Drug. Circ.* 71, 618 (1927).
  23. Co. memo to author; *Fortune* 62 (Feb. 1940).
  24. *Drug. Circ.* 77 (Nov. 1934).
  25. V. Leonard, *Science* 62, 408 (1925); Leonard and A. Wood, *J. Am. Med. Assoc.* 85, 1855 (1925); Killeffer, *op. cit.* 999; *Drug Chem. Mkts.* 16, 564 (1925); *Pharm. Era* 60, 210 (1925).
  26. T. B. Johnson and F. W. Lane, *J. Am. Chem. Soc.* 43, 348 (1921); A. R. L. Dohme, E. H. Cox, and E. Miller, *ibid.* 48, 1688 (1926); *Drug Mkts.* 21, 80, 142, 749 (1927); *O.P.D. Repr.* 45 (Aug. 8, 1927), 26 (Mar. 26, 1928); *Com. Fin. Chron.* 129, 648 (1929).
  27. Co. memo to author; *Drug. Circ.* 74, 70 (1930).
  28. *Chem. Met. Eng.* 30, 602 (1924); *Drug Chem. Mkts.* 14, 1173 (1924).
  29. *Survey of American Chemistry (1925-26)*, I, 151.
  30. *Drug Chem. Mkts.* 10, 513 (1922).
  31. *Ibid.* 16, 1029 (1925).
  32. *Chem. Mkts.* 27, 590 (1930).
  33. *O.P.D. Repr.* 54 (Nov. 9, 1925); *Moody's Manual of Investments, Industrials, 1925*, p. 1544.
  34. *Drug Chem. Mkts.* 17, 1907 (1925); *O.P.D. Repr.* 21 (Mar. 1, 1926); *Stand. Corp. Rec.* 9114 (July 17, 1926).
  35. *Drug. Circ.* 52 (Sept. 1925); *Moody's Manual, op. cit.* 1945; *Drug Chem. Mkts.* 17, 361, 503 (1925).
  36. *Soap* 42 (Sept. 1925).
  37. *O.P.D. Repr.* 65 (Feb. 7, 1929).

## Chapter 16

### THE FINE CHEMICALS

POWERS-WEIGHTMAN-ROSENGARTEN AND MERCK MERGER—ETHYL GASOLINE MAKES BROMINE BIG-TONNAGE CHEMICAL—OIL AND SALT WELLS WORKED FOR HALOGENS—CHLORINE AND IODINE TESTED MEDICINALLY; ANESTHETICS IMPROVED; NEW ALDEHYDES, ALCOHOLS, ESTERS PRODUCED—PFIZER FERMENTATION CITRIC ACID SPURS PACIFIC CITRUS BY-PRODUCTS RECOVERY—NEW TECHNIQUES, NEW USES, HIGHER DUTIES CHECK FOREIGN MONOPOLIES OF MEDICINAL RAW MATERIALS.

**A**MONG THE MANY MERGERS of these years, a few stand forth as prominently as a mesa rising against the desert horizon: Monsanto's purchase of Merrimac; Cyanamid's diversified expansion through Calco, Heller & Merz, Kalbfleisch, Selden, and the Nitrogen Engineering Corporation; the alcohol consolidations of General Industrial and American Commercial; the German-promoted General Dyestuff; and the amalgamation of two historic firms, Powers-Weightman-Rosengarten and Merck.<sup>1</sup> This last was the outstanding event in the field of fine chemicals.

This consolidation was significant in several ways. Aside from the age and world-wide reputation of both firms, it combined two of the largest producers of medicinal, photographic, and reagent chemicals, and since each had somewhat specialized, their successor offered a virtually complete line of fine chemicals. Virile family tradition prevailed at a time when it was both popular and profitable to capitalize assets liberally with "other people's money." Public financing of such well-established enterprises would have been easy, but this consolidation was consummated privately. It completed an alliance that was chemically and commercially logical and it marked the arrival of a new generation of executives.

George Merck had died six months previously.\* In 1891, a young man of 24, he came to this country to establish the American business of the House of Merck of Darmstadt, of which his father was then the head. Under his farsighted, sinewy leadership, the business that began as an American selling agency grew into an independent manufacturing enterprise. The leading strings were cut in 1919 when he and a friendly

\* Oct. 21, 1926, aged 59, at his home in Llewellyn Park, West Orange, N. J. [See *Drug Mkts.* 19, 1029 (1926); *O.P.D. Repr.* 20 (Oct. 25, 1926).]

group headed by Goldman, Sachs & Company and Lehman Brothers, with Sullivan & Cromwell as counsel, purchased stock till then owned by the family in Germany and which during the war George Merck had turned over to the Alien Property Custodian.\* In 1925, warned by failing health, he had become chairman of the board, succeeded as president by his son, George W. Merck,† and after his death his place as director was taken by son-in-law George W. Perkins, Jr.

At the time of the consolidation with Merck & Co., in 1927, the affairs of Powers-Weightman-Rosengarten were in the hands of four brothers, George D., Adolph G., Joseph G., and Frederic, grandsons of the George D. Rosengarten who had founded the firm in Philadelphia in 1822.‡ Upon the amalgamation, the two older brothers, George D. and Adolph G. Rosengarten, though continuing to serve as directors of the new Merck & Co., retired from active business. Frederic Rosengarten became chairman of the board of the new company and George W. Merck, president.

The consolidated company had assets of roughly \$9,000,000, about \$5,000,000 of which was contributed by the Powers-Weightman-Rosengarten property. The patents, trade-marks, and good will of both firms were conveyed without payment to the new corporation which bought the "P-W-R" assets at book value, paying approximately half in 6 per cent bonds and half in common stock.<sup>2</sup> Stockholders of the old Merck & Co. were paid entirely in common stock of the new corporation, which gave them a majority of the voting shares. The new stock was placed in a ten-year voting trust with George W. Merck, Frederic Rosengarten, and Richard E. Dwight, a partner of Hughes, Rounds, Schurman & Dwight, as trustees. In addition to the officers of the company, the new board of directors included Waddill Catchings of Goldman, Sachs & Company; E. H. Green of Sullivan & Cromwell; Philip Lehman of Lehman Brothers; and George W. Perkins, Jr.

The passing of the elder statesman was also marked in another great fine chemical company. April 1, 1925, Edward Mallinckrodt, who with his two brothers had established the Mallinckrodt Chemical Works at St. Louis, § retired as active executive to become chairman of the board.<sup>3</sup> He was succeeded as president by Oscar L. Biebinger, who had been with the company 37 years, having been secretary since 1893. The vice-

\* See Vol. III, p. 292.

† George W. Merck, born in N. Y. C. in 1894, entered the family business directly after graduation from Harvard (A.B., 1915) and held various positions until his succession to the presidency in 1925. In 1942 he received hon M.Ph. from Phila. Coll. Pharm.

‡ For detailed account of the Rosengarten dynasty and the firms consolidated to form Powers-Weightman-Rosengarten Co., see Haynes, *Chemical Pioneers*, p. 26.

§ Primary authority is *Edward Mallinckrodt: A Memoir*, by Geo. Dumas Stout, privately printed, St. Louis, 1933. See also Haynes, *op. cit.* p. 143.

presidents elected at this time were Edward Mallinckrodt, Jr., Arthur C. Boylston, who later became president, and another veteran, Henry W. Huning, with 50 years' service.<sup>4</sup> The secretary was Dr. Frederick W. Russe and the treasurer, Harold W. Simpkins.\* In 1928 Edward Mallinckrodt, Sr., died.<sup>5</sup>

The Abbott Laboratories, whose founder, Dr. Wallace C. Abbott, had died in 1921, expanded during the twenties under his successor, Dr. Alfred S. Burdick,† not only into the synthetic coal-tar chemicals, but also in other fine chemical and biological chemical lines. The Dermatological Research Laboratories, pioneers in arsphenamines, had been purchased in 1922, and in 1925 the plant in the Ravenswood residential section of Chicago was sold to G. D. Searle & Company for \$300,000.<sup>6</sup> All of Abbott's manufacturing activities moved to North Chicago, and three years later, the old house of John T. Milliken & Company of St. Louis was acquired, thereby adding greatly to the manufacture of pharmaceutical preparations.<sup>7</sup>

Another change of personnel in the fine chemical group was the retirement of Henry Pfaltz as president of Pfaltz & Bauer, incorporated in 1913 as American selling agents for the fine and reagent chemicals manufactured by J. D. Riedel-E. de Haën, and Dudois & Roswell. His partner, Frank M. Bauer, became president and treasurer, with Kurt Walwer, vice-president, B. O. Hoffman, assistant treasurer, and H. D. Fredmed, secretary.<sup>8</sup>

During 1926, at its Delaware works in Marcus Hook, Pennsylvania, the General Chemical Company built a new plant for the manufacture of reagent and C.P. chemicals for its Baker & Adamson Division. ‡ The following year these operations were transferred from the Easton plant, which was discontinued.<sup>9</sup> In 1926 the May Chemical Works bought the plantsite of the M. C. S. Chemical Company in Newark so as to expand its operation.<sup>10</sup> In 1929 the Commonwealth Chemical Corporation, manufacturing saccharin, benzoates, and other fine chemicals in the Newark, New York, plant which had been acquired by the Mathieson Alkali Works in 1920, was sold to Monsanto. The Mathieson management had decided to concentrate its attention upon the alkali and heavy chemical fields.<sup>11</sup>

\* Simpkins, who died in 1935 at 50, was like Mallinckrodt, Jr., Boylston, and Russe, a Harvard man (B.S., 1907). He was born in St. Louis and joined Mallinckrodt in 1917.

† Burdick (1867-1933), son of a clergyman, born in N. Y. state, was educated at Alfred U. and Rush Med. Sch. (M.D., 1891). He practiced general med. in Fla. and Ill., where he taught for 6 yrs. (assoc. prof.) at the Med. Coll. He was ed., *Am. J. Clin. Med.*, becoming vice-pres. and asst. gen. mgr., Abbott Labs. in 1916 and pres. in 1921.

‡ General Chemical and National Aniline both had plants at Marcus Hook and after formation of Allied Chemical the latter plant was dismantled and moved to Buffalo.

In 1923 bromine, which had been in moderate demand for the production of bromides used as sedatives in medicine and as photographic chemicals, became suddenly an important industrial item. The enormously increased demand for bromine arising from the introduction of tetraethyl lead as a motor fuel anti-knock agent, was the most sensational development among fine chemicals during this period. The market was overturned and a new source of bromine had to be found.

The prospective shortage of ethylene dibromide ( $C_2H_4Br_2$ , also called ethylene bromide and bromoethylene) was not conceded without a struggle to substitute for it the cheaper, more abundant chlorine. In the combustion of tetraethyl lead, corrosive lead oxide is produced and it is the function of ethylene dibromide to change this oxide to the volatile lead bromide which escapes in the exhaust gases. During 1923, when the General Motors Chemical Company was testing tetraethyl lead in the laboratory and on the road, trial runs in the trucks of the Dayton Power & Light Company proved beyond argument that bromine was much more efficient than chlorine in correcting these spark plug and exhaust troubles.\* Since the Dow Chemical Company was producing half of the domestic bromine,<sup>12</sup> Thomas A. Boyd went to Midland where he conferred with Dr. Herbert H. Dow and the Dow managers of sales and production, G. Lee Camp and Edwin O. Barstow.<sup>13</sup> On his return to Dayton, Boyd reported gloomily that the best promise these experts could make was sufficient bromine to treat 10,000,000 gallons of gasoline, whereas he and his associates had enthusiastically envisioned a market for 2,000,000,000 gallons of leaded gas. To pin the matter down, they wired Dow for a price on 25,000 pounds of ethylene dibromine, and the reply<sup>14</sup> came back, "In six weeks, 1,000 pounds a day, 50 cents † a pound."

Here were reasons enough to make every effort to utilize chlorine and during the summer of 1924 Dr. Wilder D. Bancroft was brought from Cornell to work on this problem.<sup>15</sup> He suggested copper and sulfur compounds of chlorine, a number of which were prepared and

Subsequently General Chemical renovated the National Aniline buildings. See also Vol. III, p. 345.

\* For development of tetraethyl lead, see Chap. 24. I am heavily indebted to Chas. F. Kettering and E. V. Rippingille, who placed at my disposal invaluable, firsthand sources, two unpublished MSS, the report of T. A. Boyd, and Jas. D. Carpenter's *A Romance of Research: The Story of Ethyl Gasoline*. (W. H.)

† "The price was put at this figure to amortize the new plants and everything else connected with the project, but as I recall it, the actual facts are that we lost a good many thousands of dollars because the whole thing was canceled before we could get into any amount of production, as a result of the litigation against the use of lead in gasoline. As happens in many cases, when the price came down to 20¢, it became profitable, whereas we had lost money at the higher selling price, and substantially so." (W. H. Dow, to author, Sept. 19, 1946.)

rested without discovering a suitable substitute. At the same time, Dr. Graham Edgar, who had recently become director of research of the General Motors Chemical Company, proposed that chlorine damage might be eliminated by the use of ethylene chlorobromide. This, too—under the nickname of Ethyl-3-E—was tried out. By November, however, the search was abandoned and the bromide program officially adopted.\*

As the conviction hardened that bromide was as irreplaceable as it was necessary to the success of this new anti-knock compound, the search widened. Dr. Charles F. Kettering and Thomas Midgley, Jr., with H. G. M. Fisher of the Standard Oil Company of New Jersey, went to Midland for another conference, taking with them an experienced Standard Oil petroleum driller. The remotest possibility of increasing the brine-well capacity was explored with Dow officials. Data from the other bromine brine fields in the Ohio Valley and in the Far West were carefully checked, and half-jokingly, Dr. Herbert H. Dow said, "Well, gentlemen, it looks as if we would have to mine the ocean for bromine."

Time and again the discussion returned to this obviously inexhaustible supply. Since the bromine content of sea water is but 65 to 70 parts per million (compared with about 1,300 parts per million in natural brines) the Dow staff was of the opinion that, even if technically possible, the recovery of bromine from such a dilute raw material was infeasible from the dollars and cents point of view. Dr. Dow proposed pumping water from the Pacific Ocean over the mountains to the desert of the Southwest for concentration by solar evaporation. A padful of cost figures quickly barred that idea.

On the train returning to Dayton, Midgley had an inspiration. Why attempt to recover bromine at all, he reasoned, when what we want is an organic compound of bromine? Bromine was to be released by substitution of chlorine, according to familiar reactions, so why not recover it with ethylene? Such a process threw a new light on the feasibility of recovery from sea water. Dr. Edgar suggested aniline in place of ethylene, which would produce an insoluble compound, tri-bromoaniline,† and James P. Andrew proposed the use of twice the molecular quantity of chlorine.‡ Since the laboratory at Dayton was badly equipped to work out the practical details, the du Pont organization was approached and for a fee of \$20,000 agreed to work on a

\* The proportions finally approved were 3/5 tetraethyl lead to 2/5 ethylene bromide. On this basis 2 billion gal. leaded gasoline require 2,015,418 lb. ethylene bromide or 1,713,000 lb. of bromine. [See *Chem. Mkts.* 28, 381 (1931).]

† U. S. Pat. 1,662,305 (1928), ass. to Ethyl Gasoline Corp.

‡ U. S. Pat. 1,662,355 (1928), ass. to General Motors Research Corp.

process and for another \$20,000 to devise a commercial method of separating the tribromoaniline.<sup>16</sup>

During the autumn of 1924, while these ideas were crystallizing, the search for bromine became world-wide. Kettering, accompanied by P. H. Chase of du Pont, went to Tunis where they inspected the bromine plant at Ain-es-Serah which the French interests offered to lease or to operate upon a cost-plus basis. In the meantime, Fisher went to the Dead Sea to secure if possible a concession from the British Government to operate a bromine extraction plant, a proposal that was blocked by Sir Alfred Mond of Brunner-Mond.<sup>17</sup> To provide some sort of domestic supply a contract was made with the Dow Chemical Company for 1,000 pounds of bromine monthly for five years, at an initial price of 58 cents a pound, to be reduced 2 cents each year.

The du Pont tribromoaniline project had reached the stage of a pilot plant on the seashore at Ocean Beach, Maryland. Sand in the water was causing difficulties, and Irénée du Pont suggested that the whole operation be transferred to shipboard and sent to sea. The process had been reduced to manufacturing practice due largely to the work of E. R. Armstrong and R. L. Kramer, and the steamer *Lake Harminia* was purchased. At the drydock of the Bethlehem Steel Corporation at Wilmington, she was equipped with chlorinating apparatus and a storage capacity for 80 tons of chlorine in cylinders. Rechristened the *Ethyl*, she sailed March 20, refitted to handle, by counter pipe line, 480,000 gallons of sea water an hour.<sup>18</sup>

Transformed thus into a chemical factory, the *S. S. Ethyl* sailed down the Delaware, April 25, 1925, steaming out of Chesapeake Bay to a position in the Gulf Stream 250 miles east of the Virginia Capes. Here the pumps were started and she cruised slowly south to a point offshore from Wilmington, North Carolina, and thence back to the Delaware River.<sup>19</sup> Though many of the landlubberly chemists and engineers suffered from seasickness, it was an unexciting voyage. The equipment performed satisfactorily and the recovery of bromine was beyond expectation. Preliminary estimates had anticipated an output of 100,000 pounds per month. By actual performance on the basis of a seven-hour run, recovery was at double this rate, and though the novel installation had cost \$500,000, it was announced at the time that the cost of the bromine was "not out of line."

Minute quantities of bromine extracted from the sea in a floating chemical plant captured the popular attention and the newspapers dramatized the experiment as "mining the ocean," and "robbing Father Neptune." But its most practical results were indirect. The cruise of the *S. S. Ethyl* naturally stirred the Dow organization, which could not view with equanimity the entrance of du Pont in the bromine field as



OSCAR L. BIEBINGER



ALFRED S. BURDICK



*Chemical & Metallurgical Engineering*

FREDERICK W. RUSSE



ARTHUR C. BOYLSTON



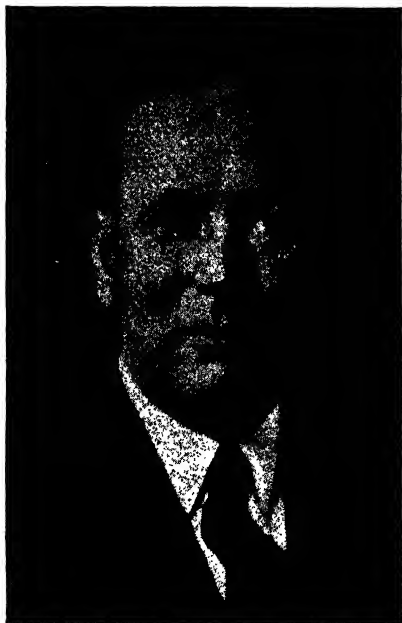


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**GEORGE W. MERCK**



**FREDERIC ROSENGARTEN**



**G. LEE CAMP**



**MAX Y. SEATON**

a large producer. All the Dow experience and technical ingenuity were bent to adapt the Dow process to extraction from the exceedingly dilute raw material. It was found that the process employed at Midland would work on sea water provided the pH was scrupulously controlled, with the obvious advantage that this method produced bromine itself, and bromine from sea water became practical only after delicate automatic control of pH had been developed. As a token of success, Dow volunteered to lower the price of bromine on the Ethyl Gasoline contract.<sup>20</sup>

From the Dow point of view, the ban on the sale of leaded gas for investigation of its alleged health hazard, was a timely stopgap. Before sales were reopened, Dow was fully prepared to undertake commercial extraction of bromine from sea water in any quantity. Accordingly, during July 1930, a preliminary survey of the southwestern seacoast was made by Roy H. Osmun to determine the most advantageous plant location. The hunt narrowed to the Carolinas, and the site eventually selected was Kure Beach,\* 20 miles below Wilmington, on the spit of land between the mouth of the Cape Fear River and the Atlantic Ocean.<sup>21</sup>

To these kaleidoscopic developments bromine reacted promptly. The price which had come down after the war to 25-27 cents a pound advanced to 30 cents in 1923 and a year later to 47 cents, remaining substantially at this figure throughout the rest of this decade. Imports, which had been negligible, increased sharply. The old German Bromine Convention had been revived at the end of hostilities. Having been taught a sharp lesson by Dr. H. H. Dow in the price contest prewar,<sup>22</sup> German producers kept out of the American market, but the German cartel had domestic difficulties of its own. Being a by-product of the Stassfurt salts, bromine became inevitably tangled with the problems of the Potash Cartel so that the syndicate which controlled practically all German and French bromides was disrupted late in 1925,<sup>23</sup> only to be gathered together again two years later.<sup>24</sup> Sales to this country increased and in 1924 reached a total of over 37,000 pounds, dropping back to 8,000 pounds in 1925, and ending the period in 1929 with 17,573 pounds.

In 1925 there was an importation of 25,000 pounds of German-made ethylene dibromide which the *Oil, Paint & Drug Reporter* noted at the time was interesting on three counts. First, the importation was not made through regular import channels by chemical merchants for resale, but by the Ethyl Gasoline Corporation, a direct consumer. Second, it emphasized the then-inadequacy of American bromine supplies for

\* The story of the Kure Beach plant, which came into production early in 1934, naturally belongs in Vol. V. (W. H.)

the new ethyl fluid. Finally, it raised conjectures whether the increased reluctance of German bromide producers to bid for the American trade was evidence of their purpose to conserve bromine supplies for the benefit of their own chemical industry to supply the enormous prospective markets for ethylene dibromide.<sup>25</sup>

Eclipsed by the spectacular efforts to wrest bromine from sea water, the great activity to recover the element from brine passed almost unnoticed. In Michigan, the American Bromine Company, whose plant near Saginaw had been shut down in January 1921, but against which the Dow patent suit had been only a partial victory,\* as the court had refused to issue an order enjoining the company from manufacturing, was bought for \$26,000 in 1922 by Isaac E. Emerson, president of the Emerson Drug Company, manufacturers of Bromo-Seltzer.<sup>26</sup> In 1926, near Lake Manistee in the western section of the Michigan lower peninsula, Ruggles & Rademaker, salt-well operators, located a brine particularly rich in bromine and containing appreciable proportions of magnesium and calcium chlorides. Instigated by Thomas Richardson, a chemical engineer, they began operations modestly in the small, then-idle plant of the Peters Salt Company with one bromine tower working brine from a single well. John L. Giles was operating manager, and in 1928 the plant was expanded by building an additional unit for the production of chlorine and soda ash to utilize to the fullest extent the production from additional brine wells. These operations hardly passed the pilot-plant stage until after 1930 when Charles H. Ruggles died and his executors, Ewald J. Pfeiffer and Charles McPherson, sold the salt plant of the old Ruggles & Rademaker firm to the Morton Salt Company for \$1,500,000. Thereafter John H. Rademaker developed these chemical activities under the name of the Rademaker Chemical Company.<sup>27</sup>

In the Far West similar projects were undertaken. In 1925, for example, the California Chemical Corporation† undertook the recovery of bromine and bought the plants and properties of the Industrial Chemical Corporation at Newark and the Whitney Chemical Company at San Mateo, entering at the same time into long-term contracts with the Leslie-California, Western, and Arden Salt Companies, for the sale in excess of 250,000 tons of solar-evaporated salt each year.<sup>28</sup> Since the early twenties this company had been the principal producer of magnesium chloride on the Pacific Coast, and the excursion into bromine was undertaken at the Chula Vista plant and later extended to San Mateo, 1927-28, and eventually to the Newark operation which at the

\* *Dow Chemical Co. vs. American Bromine Co. and Arthur E. Schaefer*; 210 Mich. Supreme Court Rept. 262 (1920). See also Vol. III, p. 288.

† In 1937 acquired by the Westvaco Chlorine Products Corp.

time, 1930, was under Paul A. Gross, works manager. During 1929 it sold over 200,000 pounds of ethylene dibromide to the Ethyl Gasoline Corporation.<sup>29</sup> The company had been organized by Stanley H. Barrows, a Chicagoan, who had been previously interested in the National Kellastone and the Sierra Magnesite Companies, while Max Y. Seaton \* was vice-president and general manager, and Charles H. Howse, the treasurer.

"Salt water" encountered in deep-well petroleum drilling was also exploited as a source of bromine. A process was evolved by Otto V. Martin whose products were said to include not only salt and bromine, but magnesium hydroxide (to be turned into magnesium chloride, oxide, and sulfate), ammonium sulfate, and the pigment, iron oxide ( $\text{Fe}_2\text{O}_3$ ).<sup>30</sup> The Sand Springs Chemical Company was incorporated for \$600,000 and a plant, operated by W. H. Colvin, Jr., of Chicago, was built at Sand Springs, near Tulsa.<sup>31</sup> The project failed to produce anything like this array of brine by-products, but two years later Dr. Martin reported<sup>32</sup> that his reorganized Martin Chemical Company had achieved a daily output of 75 tons of calcium chloride. Later the project was backed by the Texas Company under the name of the Texaco Salt Products Company.

While it entertained no illusions about paint pigments or bromine, the Strauffer Chemical Company extended its operation in soda and potash products from brine, purchasing land at Richmond, California, in 1927, and erecting a new plant.<sup>33</sup> Two other California producers of calcium chloride from brine, California Rock Salt at Saltus and Saline Products Company at Amboy, as well as the Saginaw Salt Products Company in Michigan, all explored the possibility of producing bromine,<sup>34</sup> but without results. Throughout the period, aside from the "flowing-out process" output of Dow, the chief domestic source continued to be the acid-oxidizing process of salt brine in Ohio and West Virginia. Here one of the oldest and the largest producer was the J. Q. Dickinson & Company, Malden, West Virginia. Other producers were the Pomeroy Salt Corporation and the Excelsior Salt Works in Ohio and in West Virginia, the Liverpool Salt & Coal Company, the Ohio River Salt Company, and the Westvaco Chlorine Products Corporation.<sup>35</sup>

Bromine's chemical kinsman, chlorine, had a turn as a medicinal chemical at this time. During the nation-wide flu epidemic of 1918 it had been observed that employees in electrolytic plants and plants engaged in the manufacture of war gases containing chlorine appeared

\* Seaton was with Dow, 1919-21, prior to becoming exec. vice-pres. and tech. dir. of California Chemical. Upon affiliation with Westvaco, he moved to N. Y. C. as tech. dir. of this co. and its subsidiaries, and is now exec. vice-pres. He was born in Ohio in 1890 and won his B.S. at Case in 1912. His first position was with Arco Co. and during World War I he was chem. engr. with the War Gas Div., Bur. Mines.

to be practically immune to the disease. Harrison Hale,\* widely experienced in water chlorination, set up a chlorine gas chamber at the University of Arkansas and reported that students and faculty members who remained exposed to the gas half an hour a day developed a conspicuously low number of flu cases.<sup>36</sup> Similar experiments at Camp Perry during the epidemic of 1922 and tests with regular cases of bronchitis, led General Amos A. Fries of the Chemical Warfare Service to investigate, and Lieutenant-Colonel Edward B. Vedder and Captain Harold P. Sawyer set up a test chamber at Edgewood Arsenal. They concluded that chlorine gas, properly handled, decidedly retards the growth of organisms in the upper respiratory tract.<sup>37</sup> Subsequent investigations garnered a sheaf of conflicting reports and the final verdict was that for respiratory diseases chlorine is more valuable as a preventive than a cure.<sup>38</sup>

The third halogen, iodine, established during the 1920's its usefulness in the prevention and treatment of goiter. By 1924 at least one American city, Rochester, New York, began adding it at regular intervals to the domestic water supply, and one salt company, the Canadian Salt Company of Windsor, Ontario, had placed on the market an iodized table salt.<sup>39</sup> But the center of interest continued to be the price and supply of this interesting element and the salient event of the decade was the birth of a domestic iodine production.

Although there was a widely scattered production of iodine from seaweed<sup>40</sup> in Northern Europe, Japan, and Russia, from salt springs in Surabaya, Java, and from the iodates found in the Stassfurt salt deposits, three-quarters of the world's 2,000,000 pounds' yearly consumption came from the recovery of the iodides found in the nitrate deposits of Chile. Production was controlled with an iron hand by the *Combinación de Yodo*. World prices were dictated by the so-called Iodine Syndicate in London, which, January 1923, announced an advance of resublimed iodine to 21 shillings per pound. The quotation in New York at the time moved from \$3.80 to \$4.55. Next year the price rose to \$4.65, where it stayed through 1929.

At these prices the use of iodine was confined to medicinal preparations, to photography, to a limited extent in dye synthesis, and as a

\* Head of the Chem. Dept., U. Ark., 1918-45, Hale has been a prominent figure in scientific and community activities. Since 1911, when he was chem. of the Springfield, Mo., Water Plant, he has been a recognized authority in this field. He has served as pres., Fayetteville Chamber of Commerce, and chmn. of the city's centennial celebration in 1928. He has headed the Ark. Sect. and Divisions of Chem. Educ. and Hist. Chem., Am. Chem. Soc. A contributor to the *Handbook of Chemistry & Physics*, and author of several standard works on water supplies, Dr. Hale is also chemical historian, his *American Chemistry* having gone to 2d ed. He was born in Miss., 1879, and holds degrees from Emory (A.B., 1899), Chicago (M.S., 1902), U. Pa. (Ph.D., 1908), and Drury, (LL.D., 1928).

reagent chemical. It was pointed out<sup>41</sup> that if the restrictions on output were lifted and but a fifth of the element contained in the *caliche* treated for the recovery of sodium nitrate was extracted, the cost might be lowered to about 50 cents a pound. However the monopolists were deaf to the suggestion that liberal supplies at drastically lowered prices stimulate research on industrial uses, which would enormously extend the demand.

Whether goaded by criticism, encouraged by the marked increase in the use of iodine in the treatment of goiter, or frightened by the prospect of an American production of iodine from California oil brines, the Syndicate's agency in this country, the Iodine Educational Bureau, did make a step to promote new uses. January 1, 1928, it established a fellowship at the Mellon Institute with this objective. The following year it set up a scholarship at the Philadelphia College of Pharmacy to investigate the newer organic chemicals as possible vehicles and solvents for iodine and iodine compounds, and another at Pennsylvania State College to study the nutritional value of iodine in feeding livestock.<sup>42</sup> At the same time the producers' association ran into difficulties with the Chilean Government which branded control of output and price as antiquated and threatened intervention unless different arrangements were made. The result was that the Syndicate notified its American representatives that its exclusive sales concession would end June 30, 1929.<sup>43</sup> A more serious threat was the actual appearance on the New York market, during the summer of 1929, of iodine from oil-well brines by two American producers, the General Salt Company and the Jones Chemical Company.<sup>44</sup> The latter company, managed by Coulter W. Jones,\* operated first in Louisiana and later in California where it was taken over by the Dow Chemical Company. The name was changed to the Io-Dow Chemical Company and later to the Iodine Division and eventually became a part of the Dow Great Western Division.

Mercury, another pharmaceutical raw material under foreign control, had a soaring price history during the twenties, advancing from \$48 per flask of 76 pounds in 1922 to \$132.50 in 1928.† Tied tightly to the cost of the metal, the price of mercurials, though showing less frequent fluctuations, went up markedly, mercurous chloride (calomel) in kegs, advancing from 82 cents a pound in 1922 to \$2.05 after 1927. In both the metal and its salts, the effect of these high prices was to cancel out

\* Jones, who graduated from U. Ark. in 1905 and was given an LL.D. in 1933, was with the Dow Chemical Co. for several yrs. before heading up this project. He did much research on iodine processes and held a score of patents. (H. Hale, to author, Sept. 30, 1946, and W. H. Dow, *ibid.*, Sept. 19, 1946.)

† See Appendix IV for prices, 1922-29; Appendix V for imports; Appendix VI for exports.

the higher duties of the Fordney-McCumber Tariff.\*<sup>45</sup> The wryly true saying, "When mercury reaches \$75 a flask, then American mines can come into profitable production," was again confirmed, for after 1926, when the price reached \$100, domestic production stepped up from 7,541 flasks to 23,682 in 1929, while imports dropped from 25,634 to 14,917 flasks.<sup>46</sup>

High prices were not the only encouragement to American producers. In 1923 the first mercury vapor boiler had its successful operating try-out. After years of experiment, William LeRoy Emmet† of General Electric perfected the process of vaporizing mercury in a boiler, using the vapor to generate power in a turbine, and then condensing the vapor by means of water which is converted thus into steam that may be used in an additional steam turbine or in other ways. In 1923 a trial installation was made at the Dutch Point plant of the Hartford Electric Light Company with a capacity of over 5,000 horsepower, employing 28,000 pounds of mercury. It established by trial 52 per cent greater output of electricity for the equivalent fuel consumption,<sup>47</sup> and has continued in successful operation.

California continued to be the principal production center of American mercury and the famous New Idria Mine, the outstanding single producer. There was a growing output from the Big Bend of Texas, where the Chisos Mining Company operated. Revived interest in mercury mining led in 1927 to the organization of the International Mercury Corporation, incorporated for \$5,000,000, which purchased the Cambria Mine in San Luis Obispo County, California, and reopened it with new equipment.<sup>48</sup> The company also acquired other cinnabar properties on the Pacific Coast, and its president, J. B. Treadwell of Los Angeles, associated with D. A. Knapp, H. J. Bartlett, and M. D. Webb, organized the American Mercury Company of Reno, Nevada, with a capitalization of \$500,000.<sup>49</sup>

An important change in the sale of imported mercury took place in 1925 when the old English house of Alexander Pickering & Company closed its New York office, turning over its important sales agencies, together with its manager, Charles S. Wehrly,‡ to Henry W. Peabody

\* Duty on mercury was 10% in the Act of 1913 and 25¢ per lb. in the Act of 1922; on mercury preparations, 15% and 45%, respectively.

† Emmet (1859-1941), a Naval Acad. graduate, was an outstanding engr. of his day, and his work on turbines, electrical propulsion of ships, and the mercury vapor boiler won for him hon. degrees from Union, Trinity, and Stevens, and the Edison, Elliott Cresson, Taylor, and John Scott medals.

‡ A shrewd, well-informed trader in world markets, Wehrly was chem. advisor of the Reparations Comm. in London, where he was with Pickering, 1919-22, returning to N. Y. as mgr. of the Chem. Dept. He remained with Peabody till 1932, when he joined the Merchants Chemical Co. He was born in Somerville, N. J., 1890, educated at Rutgers and Columbia, and died in 1945.

& Company.<sup>50</sup> In the meantime the mercury cartel, Mercurio Europeo, which had suffered a variety of political and commercial vicissitudes, was reorganized by the Spanish and Italian producers in 1928 and the following year offered a prize of £5,000 for the discovery of new uses for the metal.<sup>51</sup>

The prospect of freedom from Italian control over citric acid in 1923, when Charles Pfizer & Company brought its fermentation process into commercial production, was made thoroughly good by 1928, when imports of the crude material—calcium citrate—totally ceased.<sup>52</sup> As a matter of fact, the Italian Government rather desperately overplayed its hand in this important fine chemical. After the war an embargo had been placed on the exportation of lime citrate to encourage the export of this waste by-product from citrus fruit in the finished form of citric acid. This furnished the impetus not only to the commercial perfection of the fermentation process\* in the United States, but to a better utilization of the waste products of our California citrus industry.

During the First World War, the Los Angeles Laboratory of the Bureau of Chemistry had begun investigations with the object of developing processes for the recovery of citric acid, lemon and orange oils, juice, pulp, and other citrus by-products. When the Tariff Act of 1922 restored the 7 cents-a-pound duty on lime citrate, but placed concentrated citrus juices on the free list, the Italians not only centered their sales efforts on the latter, but attempted to absorb the cost differential by an export duty of their own.<sup>53</sup> With this encouragement West Coast growers organized the California Citrus League and by 1926 there were two by-product plants for lemons at Corona and one for oranges at Ontario. These achieved an output of approximately 2,000,000 pounds of citric acid, 65,000 pounds of lemon oil, 50,000 pounds of orange oil, and 30,000 pounds of pectin.<sup>54</sup> While the output of this by-product industry eventually reached over 2,500,000 pounds of acid yearly, and was further supplemented by 1,000,000 pounds from Hawaiian pineapple juice, it was the fermentation acid of Charles Pfizer & Company that literally broke the Italian monopoly.<sup>55</sup>

The coal-tar hydrocarbon gases, ethylene and propylene, were introduced as anesthetics during the 1920's. The former first came into use as a general inhalation anesthetic in 1923, following experiments by Drs. W. E. Brown, A. B. Luckhardt, and J. B. Carter.<sup>56</sup> Two years later Drs. Lloyd K. Riggs and Harold D. Goulden reported that propylene† not only was less explosive but produced a prolonged period of analgesia.<sup>57</sup>

\* See Vol. III, p. 52.

† Unlike ethylene, propylene has not been officially accepted as an anesthetic.



Disposal of war-surplus stocks of both chloroform and ether continued to be marked by the seizure and destruction of deteriorated material. For example, the U. S. Marshal at Baltimore in 1923 destroyed 1,720 quarter-pound cans of chloroform by order of the Federal Court and as late as 1929, 108,300 quarter-pound tins of ether were seized by the Food, Drug and Insecticide Administration at Bayway, New Jersey.<sup>58</sup> An improvement in the Dow process for the manufacture of chloroform \* was made in 1924 by Charles J. Strosacker,<sup>59</sup> and a great deal of good, constructive work was done in maintaining the stability of ether. An exhaustive search to this end was carried on by Squibb under Ferdinand W. Nitardy† and Mark W. Tapley,<sup>60</sup> and in the laboratory of the Food, Drug and Insecticide Administration.<sup>61</sup> As a result, the number of cans of ether officially condemned dropped from 34 per cent in 1926 to 9 per cent in 1929.<sup>62</sup>

Though of greater importance in the industrial field, the aldehydes used in medicine were importantly affected during the twenties by the commercial development of this group by the Niacet Chemicals Corporation and the Rubber Service Laboratories Company. Roessler & Hasslacher, which acted as sales agents for Niacet, offered in 1926 acetaldehyde, paraldehyde, aldol, and crotonaldehyde.<sup>63</sup> The same chemicals were on the market the following year from Rubber Service,<sup>64</sup> and during the tariff revision hearings of 1929 it was brought out that the annual consumption of paraldehyde, U.S.P., was in the neighborhood of 20,000 pounds and both companies made a plea for adequate protection.<sup>65</sup>

Other testimony submitted at these tariff hearings throws interesting lights on the state of the fine chemical industry at this time. Because of government restrictions on their raw material, ethyl alcohol, Mallinckrodt and Merck presented a joint brief through Dr. Fred W. Russe, asking for a 2 cents increase in the duty on ethyl ether—from 4 to 6 cents a pound.<sup>66</sup> Admitting that the duty adequately protected bulk ethyl chloride, the Franco-American Chemical Works applied for a raise from 25 per cent to 50 per cent ad valorem on this chemical in tubes.<sup>67</sup> It estimated a loss of between 50,000 and 75,000 tubes during the past year in competitive bidding against importers, an example of the adroitness of European manufacturers in taking advantage of any soft spots in our tariff rates. Both domestic producers of chloral hydrate,

\* U. S. Pat. 1,801,887, filed Dec. 9, 1924, granted Apr. 21, 1931.

† Nitardy was born in Germany and educated in the Middle West, with a Ph.G. and Ph.C. from Northwestern U. Coll. Pharm. He joined Squibb in 1917, later becoming gen. supt. of chem. labs. in New Brunswick, N. J., and chem. and pharm. labs. in Bklyn., N. Y. From 1930-40 he served on the U.S.P. Revision Comm. In 1943, as tech. dir. and vice-pres., E. R. Squibb & Sons Inter-American Corp., he supervised the construction of a plant in Mexico City, retiring 3 yrs. later.

Merck and Monsanto, requested an increase from 46 per cent to 60 per cent ad valorem, pointing out that European competitors had renewed their selling activities and that American manufacturers were handicapped by the high cost of alcohol.<sup>68</sup>

Another joint brief by domestic producers—the Philip Carey Company of Cincinnati and Keasby & Mattison Company of Ambler, Pennsylvania—asked more protection for calcined magnesia, reporting that imported material was being offered at 18 to 25 cents a pound, while the best price of the American producers was 40 to 45 cents a pound.<sup>69</sup> Keasby & Mattison stated specifically that because of foreign competition, chiefly English, their sales of this medicinal chemical had fallen off 600 barrels during 1928 and that they were able to keep only one of three furnaces in production. Higher duty on hexamethylene-tetramine was urged by the Heyden Chemical Corporation, which presented an array of facts supporting its contention of ruthless foreign competition.<sup>70</sup>

While the pressure of foreign makers to regain their old place in the American market continued, American makers of fine chemicals strengthened their position and added a great number of new alcohols, esters, and aldehydes. For example, the Kessler Chemical Corporation<sup>71</sup> began selling butyl tartrate and stearate in 1927. Other stearates had already increased in importance, as evidenced by the fact that the Malinckrodt Chemical Works, which had first experimentally produced aluminum stearate in 1903, found the compound of sufficient importance to justify commercial production in 1923.<sup>72</sup>

Lithium salts also attracted increasing attention, especially for new chemico-metallurgical uses. In 1929 it was reported that the largest American producer, the Etta Mine in the Black Hills of North Dakota, shipped about 1,000 tons of spodumene, the raw material, to the Maywood Chemical Works in New Jersey, sole manufacturers of lithium products in the country.<sup>73</sup> Bismuth supplies also achieved independence in 1927 when the two American producers, the U. S. Smelting, Refining & Mining Company and the American Smelting & Refining Company, both reduced their prices below European parity plus the duty of  $7\frac{1}{2}$  per cent on the European value.<sup>74</sup> This was due not to any further discovery of bismuth-bearing ores, but to the development of more intensive and better electrostatic and baghouse treatment of lead dust and fumes, resulting in a more efficient recovery of bismuth as a by-product.<sup>75</sup> The American position in borax was fortified in 1926 by the discovery of rasorite\* deposits exploited so promptly and economically,

\* A hydrated form of sodium borate, named after the discoverer of the first deposit in Calif., C. M. Rasor, mining engr. of the Pacific Coast Borax Co., which undertook the exploitation of this mineral. See Chap. 9.

that with the output of the American Trona Company at Searles Lake they took the leadership from the historically famous mine in Death Valley.<sup>76</sup>

The twenties, although a period of readjustment and extraordinary competition, saw the American fine chemical industry grow in size and strength. While the tonnage of its multitude of products is unimpressive compared with the consumption of industrial chemicals, nevertheless in the gross it had kept pace with the tremendous chemical expansion of the country during these years. It had become, in fact, one of the important consumers of basic chemicals. In 1927 it was estimated that the manufacture of fine and medicinal chemicals in this country consumed 10,000 short tons of salt, 13,000 tons of sulfur, 10,000 tons of liquid chlorine, 30,000 tons of soda ash, 50,000 tons of sulfuric acid, 50,000 tons of lime, and 30,000,000 wine gallons of denatured alcohol.<sup>77</sup>

#### REFERENCES

1. *Drug. Circ.* 71, 628 (1927).
2. *Drug Mkts.* 20, 559 (1927); *O.P.D. Repr.* 21 (May 16, 1927).
3. *Drug Chem. Mkts.* 16, 951 (1925).
4. Haynes, *Chemical Pioneers*, p. 160.
5. *Drug Mkts.* 22, 186 (1928); *O.P.D. Repr.* 24 (Feb. 6, 1928).
6. *Drug Chem. Mkts.* 17, 229 (1925).
7. Co. memo to author; Co. prospectus, Nov. 12, 1936.
8. *Chem. Mkts.* 20, 123 (1927).
9. Co. memo to author.
10. *Chem. Mkts.* 19, 1204 (1926).
11. *Ibid.* 27, 584 (1930).
12. *Min. Ind.* 1923, 90.
13. Boyd, Res. Lab. Div., General Motors Corp., *Rept.* OC-83, June 8, 1943.
14. *Ibid.*; J. D. Carpenter, *A Romance of Research*, unpub. MS, N.D.
15. Boyd, *op. cit.*
16. C. R. De Long, *Ind. Eng. Chem.* 18, 425 (1926); Boyd, *op. cit.*
17. Boyd, *op. cit.*
18. *Drug Chem. Mkts.* 16, 871, 1023 (1925).
19. Best account of this historic voyage in C. M. A. Stine, *Ind. Eng. Chem.* 21, 434 (1929); see also, L. C. Stewart, *Chem. Ind.* 41, 15 (1937); *Drug Chem. Mkts.* 17, 79 (1925); *O.P.D. Repr.* 67 (Mar. 30, 1925).
20. Boyd, *op. cit.*
21. *Chem. Met. Eng.* 41, 402 (1934).
22. *Drug Chem. Mkts.* 4 (Oct. 3, 1917); see also Haynes, *op. cit.* p. 274.
23. *Drug Chem. Mkts.* 17, 1403 (1925).
24. *Drug Mkts.* 20, 82 (1927).
25. *O.P.D. Repr.* 19 (Apr. 27, 1925).
26. *Drug Chem. Mkts.* 10, 457 (1922).
27. *O.P.D. Repr.* 63 (Mar. 26, 1928); Stewart, *op. cit.*; E. W. Pfeiffer, *Chem. Ind.* 41, 576 (1937).
28. *Chem. Met. Eng.* 34, 324 (1927); *Chem. Mkts.* 21, 10 (1927).
29. M. Y. Seaton, to author, Sept. 23, 1946; *Chem. Mkts.* 20, 555 (1927); *O.P.D. Repr.* 47 (June 30, 1930).
30. *Chem. Met. Eng.* 34, 484 (1927).
31. *Ibid.* 783; *Chem. Mkts.* 21, 784, 847 (1927).
32. *O.P.D. Repr.* 47 (Jan. 6, 1930).
33. *Chem. Mkts.* 20, 483 (1927).
34. *Min. Res.* 1927, II, 111.
35. *Ibid.* 110; *Min. Ind.* 1927, 69.
36. H. Hale, *Ind. Eng. Chem.* 12, 806 (1920).
37. Vedder and Sawyer, *J. Am. Med. Assoc.* 82, 764 (1924); 84, 361 (1925).
38. H. L. Gilchrist, *Trans. Am. Electrochem. Soc.* 49, 197 (1925).
39. D. H. Killeffer, *Ind. Eng. Chem.* 16, 995 (1924); *Drug Chem. Mkts.* 15, 639 (1924); *Min. Ind.* 1924, 100; J. W. Turrentine, *Sci. Monthly* 20, 27 (1925).
40. F. T. Shutt, *Analyst* 55, 389 (1930).
41. J. B. Faust, *Ind. Eng. Chem.* 18, 808 (1926); *Min. Ind.* 1927, 69; see also G. M. Dyson, *Chem. Age (N.Y.)* 22, 362

- (1930); P. F. Holstein, *Chem. Met. Eng.* 39, 422 (1932).
42. *J. Am. Pharm. Assoc.* 18, 1275 (1929).
  43. *Chem. Mkts.* 20, 590 (1927); *Drug Mkts.* 22, 506 (1928).
  44. *Drug Mkts.* 25, 496 (1929); O.P.D. *Reptr.* 21 (Apr. 7, 1930); Dow Chemical Co. prospectus, Dec. 15, 1936, p. 6.
  45. F. W. Russe, Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. I, Jan. 7, 1929, p. 25.
  46. For reviews of this period, see C. S. Wehrly, *Chem. Mkts.* 26, 245, 482 (1930).
  47. *Min. Res.* 1923, I, 40, 43; *Min. Ind.* 1923, 587.
  48. *Chem. Mkts.* 20, 323, 554 (1927).
  49. *Ibid.* 21, 758 (1927).
  50. *Drug Chem. Mkts.* 17, 637 (1925).
  51. *Min. Ind.* 1928, 542; 1929, 560.
  52. P. A. Wells and H. T. Herrick, *Ind. Eng. Chem.* 30, 255 (1938); Tariff Comm., *Census of Dyes, 1928*, p. 131; *Chem. Mkts.* 29, 157 (1931).
  53. E. T. Cassel, Hearings, *op. cit.* p. 61.
  54. *Chem. Met. Eng.* 34, 153 (1927).
  55. A. A. Teeter, Hearings, *op. cit.* p. 55; Merck & Co., *ibid.* p. 27; *Drug Mkts.* 24, 37 (1929); Wells and Herrick, *op. cit.*
  56. Brown, *Can. Med. Assoc. J.* 210 (Mar. 1923); Luckhardt and Carter, *J. Am. Med. Assoc.* 80, 765, 1440 (1923); *Chem. Met. Eng.* 28, 787 (1923); *Pharm. Era* 59, 420 (1924); H. W. Youngken, *Drug. Circ.* 54 (Dec. 1932).
  57. *Pharm. Era.* 60, 460 (1925); Riggs and Goulden, *J. Am. Pharm. Assoc.* 16, 635 (1927).
  58. *Drug Chem. Mkts.* 12, 793 (1923); O.P.D. *Reptr.* 20 (Dec. 23, 1929).
  59. *Drug Mkts.* 29, 193 (1931).
  60. *J. Am. Pharm. Assoc.* 17, 966 (1928).
  61. *Ann. Rept.* 1928, p. 7.
  62. *Ibid.* 1930, p. 12.
  63. *Chem. Mkts.* 19, 73 (1926).
  64. *Ind. Eng. Chem., News Ed.* 13 (Sept. 10, 1927), 4 (Oct. 20, 1927); Tariff Comm., *Census of Dyes, 1927*, p. 133.
  65. Hearings, *op. cit.* p. 178.
  66. *Ibid.* p. 23.
  67. *Ibid.* p. 2781.
  68. *Ibid.* pp. 32, 241.
  69. *Ibid.* p. 462.
  70. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929, Sched. 1, June 1929, p. 192.
  71. Tariff Comm., *Census of Dyes, 1927*, p. 134.
  72. Co. memo to author.
  73. *J. Am. Pharm. Assoc.* 18, 658 (1929); Hearings Ways & Means Comm., *op. cit.* p. 453.
  74. H. R. Brush, *Eng. Min. J.* 125, 102 (1928).
  75. *Min. Res.* 1923, I, 105; *Min. Ind.* 1923, 83.
  76. E. M. Kitchen, *Am. Fertil.* 7 (Sept. 30, 1939).
  77. *Chem. Met. Eng.* 34, 586 (1927).

## Chapter 17

### DRUG PRODUCTS AND PHARMACEUTICALS

BRANDED GOODS, PRICE CUTTING, SUBSTITUTION, DISTRIBUTION RAISE NEW PROBLEMS—  
DRUG REGULATIONS TIGHTENED; “MULTIPLE SEIZURES”—FOOD, DRUG & INSECTICIDE  
ADMINISTRATION SET UP—STRICTER NARCOTIC CONTROLS—U.S. FIGHTS DUTCH QUININE  
CARTEL—EPHEDRINE INTRODUCED; CAFFEINE FROM THEOBROMINE—RESEARCHES FOR  
MALARIA, LEPROSY, HEART DISEASE, COLD REMEDIES—ALKALOID PRICES DROP—MERGERS  
PROMINENT IN PROPRIETARY FIELD.

**D**URING THE BOOMING TWENTIES, the transformation of apothecary shop to drugstore, an evolution which began in the larger cities at the turn of the century, was completed. The retailer ceased to be a pharmacist and became a merchant. This metamorphosis was accompanied by changes quite as radical in the business of the wholesaler and the drug manufacturer. Fresh points of view and new methods were introduced and, for better or worse, became irrevocably fixed.

Many diverse influences advanced this development of drug merchandising. One of the most important was the rise of the pharmaceutical manufacturing firms. These freed the druggist of the work of making his own tinctures, ointments, galenicals, and many other standard preparations, and relieved the doctor of the weighty task of formulating his prescriptions at the patient's bedside.

Most pharmacists and physicians welcomed this labor-saving opportunity. The pharmaceutical and drug manufacturers,\* eager to expand

\* “I wonder, is ‘drug manufacturer’ the right term to use? To me it implies the making of a drug, for example, acetanilide, aspirin, barbiturates, etc. Neither the pharmacist nor the pharmaceutical manufacturer ever made these, but compounded them as per prescription or proprietary formula. . . . Between the producer of straight manufactured chemicals, like aspirin, etc., and the manufacturing pharmacist, a considerable portion of the physician's prescribing was reduced to writing the name and dose of a proprietary product, and the retail pharmacist's labors were to an extent reduced to repackaging and relabeling the proprietary prescribed. I know neither would like that statement, and it is not wholly true, but there is a lot of truth in it.” (A. Merz, to author, Oct. 31, 1946.)

Dr. Merz re-emphasizes the shadowy distinctions between manufacturers in this branch of the industry. For what to him is a drug manufacturer I have used the term “fine or medicinal chemical maker,” and “pharmaceutical manufacturer” for the maker of U.S.P. and other standard preparations, while a “drug manufacturer” is a maker of proprietary preparations sold ethically on prescription through the druggists, and a “proprietary manufacturer” sells medicinal preparations direct to the public. From pharmaceutical

their business and make the most of the economies of large-scale standardized production, cheerfully assumed the grave responsibilities of both professions for prepared medicinal preparations. Of necessity their activities expanded far beyond making and packaging stock for the prescription department. Their new obligations could only be fulfilled by scrupulous control over every stage of manufacturing, which meant analysis of all raw materials and led to chemical and physiological testing of finished products.

"It is proper to note," Josiah C. Peacock told<sup>1</sup> the 1926 meeting of the American Pharmaceutical Association, "that production has voluntarily and deliberately, as well as necessarily, sought all of this responsibility and has so ably and dependably met its every phase that the dispenser who relinquishes it does so with every confidence."

Inevitably, therefore, American pharmaceutical manufacturers began to make important contributions to analytical methods and to the establishment of standards for purity of product and therapeutic performance. These activities embraced a wide variety of chemical and biochemical researches, carried on by their scientific staffs in their own laboratories and in institutional laboratories by collegiate researchers supported by grants from these manufacturers, which led to the discovery and commercial application of numerous new synthetic medicinal chemicals and culminated during the thirties in the vitamins\* and hormones.

Some strictly commercial elements also influenced the entire drug trade importantly during these years. One was the widespread introduction of branded packaged goods. Another was the competition of the department and chain drugstores. The two were interwoven in cause and effect. Neither was a new influence, but both became characteristic elements typical of and controlling the merchandising system.

In every sector of the drug trade packaged goods spread rapidly. Bulk stocks of Epsom salt and Dover's powder, of chloroform liniment and tincture of iodine, and literally hundreds of such standard items in bins and stock bottles were replaced by tins and cartons, jars and bottles of appropriate sizes for individual sale. The convenience, the saving of time and effort, the elimination of waste and spoilage, and the protection against careless weighing and dispensing, all appealed strongly to the retailer. Consumer acceptance of branded packages was also prompt

to proprietary in all classes there is much overlapping and the distinctions, though well established by trade custom, defy definition in a literal sense. (W. H.)

\* Although the first vitamin, C, had been discovered by Casimir Funk in 1909 and vitamins A, B, D, and E had all been identified, isolated, and with the exception of E marketed by 1929, nevertheless, the thirties were so conspicuously the period of vitamin development on an industrial scale, that for the sake of continuity the entire vitamin story is best told in Volume V. (W. H.)

and enthusiastic. Drug and pharmaceutical manufacturers vied in packaging every item in the U. S. Pharmacopeia and out of it. Packaged items became a prominent part of the so-called "cooperative lines" such as United Drug's Rexall and Frederick Stearns' Nyal. Wholesalers, too—notably the mutual jobbers—became "packing houses," and this business loomed large in the McKesson & Robbins chain which was organized during the twenties. Private label houses offered aggressive retailers the opportunity to merchandise products under their own brands.

This change in merchandising methods magnified the brand which became both a stamp of identification and a hallmark of quality. It underscored the truism aptly expressed in the familiar Squibb slogan that "the priceless ingredient of every product in the market-place is the honor and integrity of him who makes it." By making this yardstick practical for the purchaser, branded wares greatly stimulated national advertising and injected a new element into competition. By fixing the responsibility for shelf goods upon manufacturers, it increased the obligation they had already assumed for prescription preparations, and it encouraged the extra-manufacturing activities of analysis, testing, and research.

In the retail trade, branded goods facilitated the formation of chains. Their aggressive sales methods threatened neighborhood merchants, compelling them to modernize their stores and policies. At the same time the department stores, growing rapidly out of the dry-goods shop, began adding drug and cosmetic departments. Throughout all retail trade this period was characterized by a reaching out to embrace new lines, and as the cigar stores sold candy and the confectioners began serving lunch, so the druggist added a multiplicity of goods ranging from bathing caps and fountain pens to ice cream sodas and magazines.<sup>2</sup>

While jobbers and retailers were busy thus extending their lines, the manufacturers of branded drug products welcomed the new sales outlets in other trades. Backed by national advertising, they went out for unrestricted volume sales. A fresh crop of competitive problems was harvested. Price cutting and substitution became burning issues. Later, in the thirties, came a reaction. Manufacturers who had encouraged volume sales at any price, became resentful of price-cutting wholesalers and retailers whom they denounced as demoralizers, while the retail druggists, through their national trade association, opposed drug manufacturers who sold to grocers, department stores, and what not.<sup>3</sup>

The enormous number of strictly legitimate drug items regularly handled was early recognized as distinctive of the business. In 1923 C. H. Waterbury, secretary of the National Wholesale Druggists' Association, estimated<sup>4</sup> that the inventory of a retail drugstore averaged 12,000 distinct products and a wholesaler's stock ranged between 45,000

and 60,000 separate items. Obviously no retailer, however big, could afford to carry anything like a complete stock. He must have quick access to fresh supplies and to out-of-the-ordinary items. Waterbury concluded that the national market could be most economically reached through the 292 wholesale druggists serving the 48,000 retailers. He was a prejudiced witness, but his conclusions were sound. The close cohesion of the drug trade and the logic of its normal distribution through jobbers was only the more forcefully demonstrated during the twenties when at both ends manufacturers and retailers attempted to break it down.

The turmoil over price maintenance added to the confusion of these years. Chain stores precipitated the issue. But many independent druggists adopted their price-cutting tactics. However, most small retailers protested against what they called the unfair competition of their financially stronger rivals. In several localities they banded together in defense, as for example, when the New York Pharmaceutical Conference issued so-called "courtesy cards" to the salesmen of manufacturers who agreed not to sell to price cutters.<sup>5</sup> This was virtually blackmail backed by a boycott, similar to that adopted by the National Wholesale Druggists' Association the year before,<sup>6</sup> and it led to an investigation by the Federal Trade Commission.

Most drug manufacturers, jobbers, and retailers agreed that price cutting was a demoralizing and dangerous threat to stability. In each group, however, certain firms found this weapon effective in the battles to secure volume business and to break into new lines. Among those who wanted price maintenance there was no agreement on any effective means of achieving this end. "There ought to be a law," the familiar American recourse, occurred to many, but public opinion was undecided whether cut prices, an obvious advantage to the individual purchaser, were truly in the public interest. Decisions of the Federal Trade Commission and the courts reflected this confusion. Congress naturally balked at taking definite action.

In an effort to crystallize the problem, Edward Plaut, president of Lehn & Fink Products Company, offered \$10,000 in prizes for the best, legally enforceable price plan.<sup>7</sup> The winning paper by Donald F. Vliet<sup>8</sup> reviewed the recent Supreme Court decision that while a manufacturer may sell to anyone at any price, once his goods become the property of another, the new owner has the same right. In retrospect, Vliet's proposal that a simple, legal means should be made available to manufacturers who wish to control the resale price of their branded products, seems admirably fitted to have served the best interests of all.

Obviously the retailer is deeply concerned with retail prices. But in the final analysis, price is a matter of policy for the manufacturer to



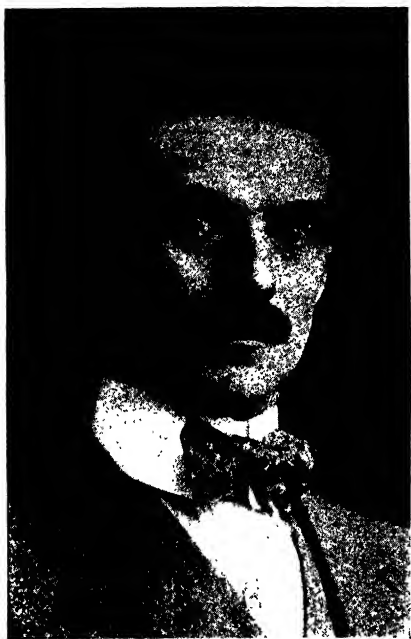
resolve himself. His is the risk and the responsibility. If his price is wrong, he is the chief sufferer. A number of manufacturers, like Men-nen, Colgate, and Armand, were ready to face the extremity of court action to protect their retail price schedules. Legislation authorizing control of prices failed chiefly because Congress, following the lead of the Federal Trade Commission, was frightened at the possibility of monopoly. At the time it was a rather pointless argument since except in the case of a few patented articles, there was plenty of competition from manufacturers keen to sell upon a cut-price basis.

Entangled with price cutting was the old drug trade dilemma of substitution upon which the Supreme Court made an important decision in 1924, drawing a fine line between fair and unfair competition. In 1899 Eli Lilly & Company put on the market a liquid preparation of quinine sulfate, yerba santa, and chocolate, trade-named Coco-Quinine. A few years later William R. Warner & Company offered Quin-Coco, described<sup>9</sup> as "substantially similar to the Lilly preparation." The evidence made clear that the salesmen of Warner and its affiliated companies, the Pfeiffer Chemical Company and Searle & Hereth, flagrantly suggested to druggists that orders and prescriptions for Coco-Quinine (Lilly) could be filled by substituting Quin-Coco (Warner) without any danger of detection.\* The Supreme Court, reversing the decision of the lower courts, ruled that while Lilly had no exclusive right to the formula, the imitator of another's goods must sell his products on their own merits and must not represent them as an equivalent or acceptable substitute.

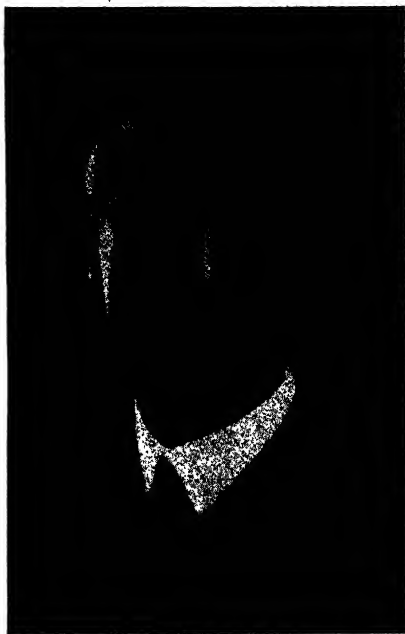
Another sign of the changes being hammered out in drug trade merchandising was legislation proposed in many states, governing the ownership of retail drugstores. Typical was the law introduced in Missouri in 1925, requiring that the proprietor of a drugstore must be a registered pharmacist, or in the case of a corporation, that 90 per cent of its stock must be owned by registered pharmacists.<sup>10</sup> Most of this legislation failed, but a majority of State Boards of Pharmacy passed more stringent regulations requiring the continual presence of a registered pharmacist in any store selling medicinal products.

Costs of distribution in the drug trade were also a matter of concern, and the first tasks set for a research division organized by the National Wholesale Druggists' Association were to devise a uniform cost-accounting system and to study comparatively the volume, turnover, and special sales effort required on a dozen big-selling proprietaries.<sup>11</sup> It is significant that a major topic of discussion at the 1929 conventions of the two

\* "Our company should not be singled out without mentioning that this was at that time a common practice, engaged in by practically all pharmaceutical manufacturers." (E. H. Bobst, to author, Nov. 15, 1946.)



ALFRED R. L. DOHME



*Drug & Cosmetic Industry*

JAMES E. BARTLETT



*Oil, Paint & Drug Reporter*

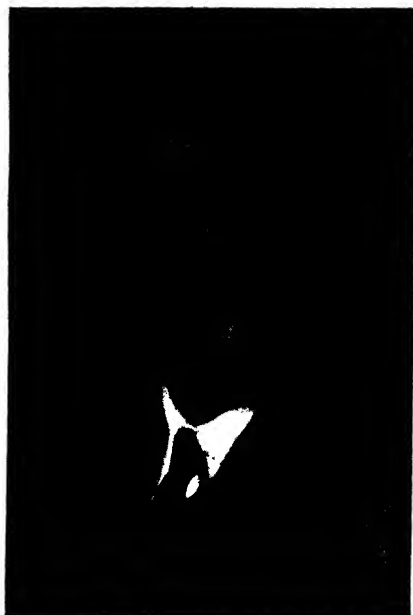
FRANK L. McCARTNEY



ELMER H. BOBST



**JAMES H. BEAL**



**ROBERT H. DE GREEFF**



**K. K. CHEN**



*Oil, Paint & Drug Reporter*

**SAUNDERS NORVELL**

leading manufacturers' associations—American Pharmaceutical and American Drug—was the cost of distribution.<sup>12</sup>

Research on drug standards, which preoccupied manufacturers during these years, was invigorated by acceptance of the spirit as well as the letter of the Pure Food Law. As Dr. James H. Beal\* reminded the National Association of Retail Druggists at their 1923 meeting,<sup>13</sup> "The moral label is no guarantee of moral content'. . . . The Pure Food and Drugs Act is a simple expression of 'The label shall tell the truth.' It does the work it is intended to do. That is an excellent test of a good law. Political terrorism does not make for good laws. There is something more potent than the penal clause. It is public sentiment." Before the American Drug Manufacturers' Association a year later, Dr. W. W. Skinner, assistant chief of the Bureau of Chemistry, which at this time was charged with the administration of both the Pure Food and Anti-Narcotic Laws, touched that same point from a different angle. He told the representatives of the industry present that safeguarding the nation's drug supply is the joint responsibility of the officials charged with enforcement of the federal laws and of the drug manufacturers.<sup>14</sup>

In 1924 and again in 1927, the Bureau of Chemistry, working through the Pharmaceutical Manufacturers' and the Drug Manufacturers' Associations, surveyed the entire field of drug preparations. Both studies were particularly aimed at determining the practical manufacturing limits of drug purity and the establishment of simpler, more rigid standards.<sup>15</sup> After the latter investigation, which lasted two years and covered more than 1,000 different products, changes in labels, necessary to comply with newly established regulations, particularly as to claims, were officially suggested to a great number of manufacturers. The majority revised their wording or their formula, and forty-five "antiseptics," which had been tested bacteriologically and found wanting, were voluntarily taken off the market. In only twenty cases did the Government have to resort to legal action.<sup>16</sup> Improvement made in hypodermic and compressed tablets was characterized by the official report<sup>17</sup> as "noteworthy," a justified adjective since the percentage of substandard samples examined dropped in six years, 1923-28, from 34 per cent to 8 per cent.

The industry complained of the administration of regulatory legislation. The gravest objection was to the practice of "multiple seizure" by which Food and Drugs Act enforcement officials seized goods

\* Chmn. of the bd. of trustees, U. S. Pharmacopoeia; inspiring teacher of pharm. at Scio Coll. (1887-1907), at Pittsburgh (1902-11), and Illinois (1914-18), and ed., *J. Am. Pharm. Assoc.* (1911-14), Beal was the outstanding authority of his day on drug legislation.

claimed to be adulterated, in more than one state simultaneously. This practice was protested legally as placing a defendant in double jeopardy, and practically as an unnecessary trouble and expense. Accordingly, in 1926 a bill to amend Section 4 of the Food and Drugs Act was introduced\* and hearings were held before the Senate Agriculture and Forestry Committee.<sup>18</sup> Theodore Rassieur of Monsanto, Henry B. Thompson for the Proprietary Association, Horace W. Bigelow, attorney for the Drug Manufacturers' Association, and W. L. Crounse of the National Wholesale Druggists' Association, all appeared in favor of this measure which was vigorously opposed by the enforcement officials of the Department of Agriculture. It failed to pass and for the two following years the National Drug Trade Conference adopted strong resolutions condemning multiple seizure as contrary to the principle of the Act.<sup>19</sup> This representative body also criticized the various state poison laws as indefinite and misleading, suggesting that future legislation mention by name the poisons covered. A committee was appointed to compile a table of toxic drugs that might serve as the basis for labeling and packaging laws and for regulations.

The new status of synthetic chemicals in *materia medica* was recognized by the influential Pharmaceutical Manufacturers' Association when in 1927 it expressed strong disapproval of any law or ruling requiring that synthetic drug and food products must be labeled "imitation." The word "synthetic," it was pointed out, is in itself a true designation of such products, free from any element of deception, and the unwarranted stigma of "imitation" tends to retard the progress of synthetic organic chemistry, the development of which is very much in the public interest.<sup>20</sup>

Administration of the multiplying laws governing drug products troubled both the industry and the enforcement officials. This was scattered through several bureaus so that contradictory rulings and conflicts of jurisdiction were inevitable. Within the Department of Agriculture the urge for simplification had a different inspiration. Enforcement of these laws was vested in several bureaus whose functions included research as well as regulatory activities. With an Administration in power to whom public debt refunding and tax reductions were definite political objectives, it was hard to obtain financial support for much-needed investigations in competition with imperative need for funds for inspection and for police work. Therefore in presenting his 1926 budget to Congress, the Secretary of Agriculture recommended that the duty of regulating and enforcing the Food and Drugs Act, the

\* This bill, S. 4235 (S. 61:1), provided for a three-man trial board appointed by the Secretaries of Agriculture, Treasury, and Commerce, to conduct hearings prior to any seizure of goods for alleged adulteration.

Tea Act, the Insecticide Act, and the Naval Stores Act, all be placed in a single unit known as the Food, Drug and Insecticide Administration, while all research work on soils, fertilizers, and agricultural chemistry in general be centered in a new Bureau of Chemistry and Soils.<sup>21</sup> Congress adopted this sensible suggestion in the Act of January 18, 1927, the reorganization to be effective July 1, 1927. The first chief of the Food, Drug and Insecticide Control was Dr. George W. Hoover, who in the spring of 1928 was followed by Dr. James J. Durrett.<sup>22</sup>

Narcotic control, which continued in the Treasury Department, was greatly strengthened within this country despite a complete breakdown of the International Opium Conference held in Geneva in May 1923. This met at the invitation of President Coolidge for the specific object of restricting production of opium gum to world requirements for its medicinal and scientific uses.<sup>23</sup> Almost immediately the deliberations became a battle between politics and pocketbooks. The delegates—chiefly diplomats, civil servants and administrators, college professors and reformers, with physicians, chemists, pharmaceutical manufacturers, and drug merchants conspicuously absent—were quite unable to agree upon a practical method of control.<sup>24</sup> After months of futile wrangling, the American delegates gave up and on February 6, 1925, Stephen G. Porter,\* their head, announced they were officially withdrawing from the conference.<sup>25</sup>

In this country, on the other hand, control over narcotics was tightened† by the Narcotic Drug Import and Export Control Act which went into effect in January 1922. Within a year imports of opium were reduced to 136,000 pounds, compared with the 1910-15 average of 471,000 pounds, and Colonel L. G. Nutt, executive head of the Federal Narcotics Control Board, reported that the illegal use of opium had come down 85 per cent and that 90 per cent of this was served by smuggled gum.<sup>26</sup> The number of addicts in the United States was estimated<sup>27</sup> to have dropped from 264,000 in 1900 to 110,000 in 1924. ‡

\* An active supporter of narcotic control, Porter (1869-1930), a lawyer with 2 yrs.' medical training, was Rep. from the 32d Dist. Pa. since 1911. He was chmn. of the House Foreign Affairs Comm. and on the Advisory Comm. of the Limitations of Armaments Conference. The other U. S. delegates at Geneva were Dr. Rupert Blue, former Surg. Gen. of the Public Health Serv., and Bishop Chas. E. Brent of N. Y., accompanied by Edwin L. Neville of the Far Eastern Div. of the State Dept. as special advisor.

† For review of current narcotic legislation, see J. W. Bevans, *Drug. Chem. Mkts.* 10, 561 (1922).

‡ The problems of addiction were studied by Bureau of Social Hygiene, Inc., organized 1921, financed by the Rockefeller Foundation, which published a survey of the literature, *The Opium Problem*, by Chas. E. Terry and Mildred Pellens, 1928, and set up a research on addiction and tolerance to morphine in animals and man. Findings in man were published in *J. Am. Med. Assoc.*, 1929-30, by Dr. A. B. Light and associates, and those in animals in Apr. 1933 issue of *J. Pharmacol.*

These results had been achieved in a great measure by strict control over raw materials. After the suspension of all import permits in 1923,<sup>28</sup> these were renewed upon a quota basis, established by the Narcotics Control Board after an investigation of estimated requirements furnished by Parke, Davis, Eli Lilly, William S. Merrell, Powers-Weightman-Rosengarten, New York Quinine, Mallinckrodt, and Merck.<sup>29</sup>

In 1926 a bill (H.R. 11612) designed to put more teeth into the Harrison Narcotics Act was introduced at the instigation of General L. C. Andrews, the special Assistant Secretary of the Treasury charged with the enforcement of both Prohibition and narcotic control. This amendment, which was energetically advocated by Colonel Nutt and other enforcement officials, enormously increased the responsibilities of physicians and druggists, and on the grounds that these duties were unreasonable and unenforceable, the measure was opposed by representatives\* of the medical profession and the drug trade.<sup>30</sup> This bill never became law, but after the Supreme Court upheld the validity of the Harrison Act, May 16, 1927 and again April 9, 1928, the regulations were tightened to plug loopholes that were revealed in the campaign to eradicate the illicit trade.<sup>31</sup>

Stricter narcotic control encouraged the development of nonhabit-forming medicinals† and inspired Herman A. Metz to offer a prize of \$100,000 for a practical method of synthesizing morphine.<sup>32</sup> Realizing that a synthetic alkaloid would be a severe blow to the cultivation of the opium poppy in China, Metz stipulated that the award should be made only for an identical synthetic product, the patent to which must be dedicated to the public.‡

Though when introduced heroine (diacetylmorphine) had been hailed as nonhabit-forming, its greater habit-forming properties had been discovered promptly, and even during World War I a campaign against its use was started by the U. S. Public Health Service. By 1922 the medical profession had agreed almost unanimously in condemning this narcotic. Since a law forbidding its manufacture was of questionable constitutionality, Stephen G. Porter in 1924 proposed an amendment to the Harrison Law, to prohibit the importation of opium for the purpose of manufacturing heroine. The hearings<sup>33</sup> brought out some interesting facts. Dr. Charles W. Richardson estimated that 76,000 ounces of heroine were sold illegally in New York each year, but that

\* Appearing against this bill at the hearings were Eugene C. Brokmeyer, atty., Nat. Assoc. Retail Druggists; Wm. L. Crounse, secy., Nat. Wholesale Druggists Assoc.; Samuel L. Hilton, atty., Am. Pharm. Assoc.; Dr. Wm. C. Woodward, Am. Med. Assoc.; Horace W. Bigelow, atty., Am. Drug Mfrs. Assoc., Parke, Davis, and Mo. State Med. Assoc.

† See Chap. 15.

‡ Metz got this idea from an address by Dr. Carleton Simon, Special Deputy Police Commissioner of N. Y., at the Internat. Police Conference in that city.

the 14,000 physicians in the state prescribed only 58 ounces. Representative Porter declared that while it is impossible for the Government to determine the purposes for which opium had been imported, nevertheless the Narcotics Control Board had life-or-death powers in its permissive licenses to manufacture. If this law were enacted, the risks of violation provided a safeguard against diversion of opium into the preparation of heroine since only eight companies were equipped for its rather difficult preparation. No manufacturer appeared in opposition to the amendment and even the physicians who testified agreed that the future of heroine lay in the hands of the medical profession. Accordingly, the Porter amendment died in committee.

Control over cocaine was also more rigid. The importation of coca leaves was strictly supervised, and as a result of a conference between the Exports' Committee of the Narcotics Control Board and the American manufacturers of cocaine, Maywood Chemical Works and Merck & Co., licenses were markedly curtailed in 1925. Sales of the alkaloid were reduced in the fiscal year of 1924 to 37,051 ounces from 57,123 ounces the previous year.<sup>34</sup> The Treasury Department issued new regulations covering the manufacture and sale of cocaine, specifically including its preparations and derivatives under the Narcotics Law.<sup>35</sup>

Another alkaloid prepared from a drug of Eastern origin, ephedrine from ma huang (*Ephedra sinica*\*) became conspicuously important. This was the renaissance of a drug used empirically by the Chinese for some 5,000 years, whose active principle had been isolated in 1885 by Yamanashi, and from which the pure alkaloid was prepared in 1887 by Nagai and Hori.<sup>36</sup>

In the laboratories of the Union Medical College at Peking, careful pharmacological studies were being made of popular native drugs, and a Chinese dealer in drugs urged his nephew, Dr. Ko Kuei Chen,† to investigate ma huang. The young American-trained pharmacologist made a concoction of ma huang in the autumn of 1923 and injected it into the veins of an anesthetized dog. The heightened circulatory effect observed encouraged Chen to continue clinical experiments in collaboration with Dr. Carl F. Schmidt.‡ They prepared the pure

\* Preferred name for *Ephedra vulgaris*, but *Ephedra equisetina* and other species are also used in the preparation of ephedrine, U.S.P. [See O. A. Farwell, *J. Am. Pharm. Assoc.* 16, 135 (1927).]

† Born in Shanghai, 1898, Chen came to U. S. as a Chinese Govt. student and earned his B.S. and Ph.D. at U. Wis. He was senior asst. at the Peking Union Med. Coll., 1923-25, returning to Wis., thence to Johns Hopkins, where he was assoc. pharmacol., winning his M.D. in 1927. Two years later he became dir. pharmacol. research for Eli Lilly & Co. where, in addition to teaching at the U. Ind. Med. Sch., he has remained since. His work on ephedrine won him the prize of the China Foundation in 1928.

‡ In 1922-24 Schmidt was assoc. pharmacol. at the Peking Union Medical Coll., having previously taught at U. Pa. where he won his M.D., 1918, after an A.B. from Lebanon



alkaloid, and the Union Medical College began the manufacture of ephedrine hydrochloride.<sup>37</sup> When both members of this research team returned to the United States—Chen to Wisconsin and Schmidt to Pennsylvania—they continued these studies,\* establishing ephedrine's low toxicity and checking its physiological reactions. The chemical laboratory of the American Medical Association set up standards for the alkaloid which in 1926 were submitted to the Council on Pharmacy and Chemistry and subsequently approved.<sup>38</sup>

Ephedrine created quite a medical sensation,† and in 1926 Eli Lilly & Company was the first American firm to introduce the alkaloid and its derivatives commercially to the medical profession.<sup>39</sup> From zero in 1925 the exports of ma huang from China (Tientsin) jumped to 224,058 pounds in 1926 and continued upward to 820,533 pounds in 1929.<sup>40</sup> Prior to 1924 but two firms in the world—one German, one Japanese—were producing ephedrine. By 1930 it was being prepared by eight firms in the United States, one in Canada, three in England, two in Germany, three in China, four in Japan, and two in India.<sup>41</sup>

The concern of Secretary of Commerce Hoover over foreign monopolies led to an anti-trust suit in quinine, one of the first attempts of this Government to weaken the grip of an international cartel upon American supplies and prices. At the time some 110 plantations in the Dutch East Indies were producing 95 per cent of the world's output of cinchona bark,<sup>42</sup> and in 1923 the contract between the growers with the cooperative, Dutch-owned factory at Bandoeng and the Dutch Kina Bureau was renewed for another five years.<sup>43</sup> As in the past, American manufacturers, because of our anti-trust laws, refused to enter into these international price agreements governing both bark and quinine salts. The market here continued to be supplied by R. W. Greeff & Company, representatives of the two Dutch manufacturers, Nederlandsche Kininefabriek and Amsterdamsche Chininefabriek and of the Java factory, Bandoengsche Kininefabriek, and by the Viotor & Hosken,‡ American agents of the Hoshi Pharmaceutical Company, which was also a member of the Quinine Convention.<sup>44</sup>

The Government's anti-trust war against the Dutch quinine monop-

Valley Coll. in 1914. He returned to U. Pa. as asst. prof. in 1924 and prof. since 1931. He was ed., *J. Pharmacol.*, 1940-42.

\* See Appendix XL for Dr. Schmidt's firsthand account.

† For a good review, see K. K. Chen and C. H. Kao, *J. Am. Pharm. Assoc.* 15, 726 (1926); for the technical literature, Nat. Res. Council, *Annual Survey of American Chemistry*, I, 144; II, 291; III, 252; IV, 280.

‡ Formed in 1923 by Carl Viotor, partner of the recently disbanded drug-importing house of Viotor & Achelis, and William Hosken, American agent of Hoshi. In addition to the Japanese quinine agency, Viotor & Hosken were sales agents for the synthetic aromatics of the C. E. Ising Corp. In 1926 Viotor withdrew and the firm's name was changed to Hosken & Co. [See *Drug Chem. Mkts.* 18, 1017 (1926).]

oly was declared in November 1927 by subpoenaing thirty firms and individuals to appear before a federal grand jury in New York.<sup>45</sup> Neither names nor charges were made public, but after this hearing the Department of Justice decided that the investigation should concentrate upon the actual importers of cinchona bark and quinine\* and that the facts would be best disclosed by individual examination at their offices and plants.<sup>46</sup> On March 5 following, these principal factors were called to Washington and told bluntly by Assistant Attorney General William J. Donovan that the Government intended to start criminal action. Soon afterwards the federal grand jury in New York began examining witnesses, among them T. S. Van Linge, son of Dr. A. R. Van Linge of the Kina Bureau, who was visiting in this country at that time.<sup>47</sup> This investigation revealed that 6,000,000 ounces of quinine were being consumed annually in the United States, about 40 per cent of the world's total, and that the market price was 40 cents an ounce. The Kina Bureau's control† of virtually the entire world's supply, through the purchase of all cinchona bark produced in Java, was established. Americans participating in the Quinine Convention activities were said to be R. W. Greeff & Company, its president, Robert H. de Greeff,‡ and treasurer, William N. Barnum; and the Hoffman-La Roche Chemical Works and its treasurer, Elmer H. Bobst.§ The New York Quinine & Chemical Works and Merck & Co., it developed, had been coerced into agreement. In an unprecedented move the Government seized five tons of quinine stored in the warehouse of the R. W. Greeff & Company and locked it up in the U. S. Army base in Brooklyn.

\*The American firms involved were R. W. Greeff & Co., Hosken & Co., Hoffman-LaRoche Chemical Works, N. Y. Quinine & Chemical Works, Merck & Co., and Mallinckrodt Chemical Works. The Dutch firms charged with monopolistic practices were the *Amsterdamsche Chininefabriek*, the *Nederlandsche Kininefabriek*, and the *Bandoengsche Kininefabriek*.

† "The Quinine Convention was a cartel whose members were all the quinine manufacturers of the world, with the exception of the two American firms (P-W-R and N.Y.Q.). The Kina Bureau was an organization in which only the three Dutch manufacturers and the Association of Cinchona Bark Producers in Java were represented for the purpose of regulating their relationship. The Dutch manufacturers were not alleged to have formed the Kina Bureau, which has probably always been dominated by the plantation interests, but they did, no doubt, dominate the Quinine Convention." (R. H. de Greeff, to author, Nov. 4, 1946.)

‡ Scion of the old Dutch-English drug-trading family, Robert de Greeff was born in Frankfurt, 1884, and educated in Germany, studying chem. under Fresenius at Wiesbaden. In 1906 he joined R. W. Greeff & Co. in London and came to N. Y. in 1914 in charge of the American company.

§ Bobst climbed from drug clerk to co. pres. After 5 yrs. in a retail store he became salesman for F. Stearns & Co. (1907-9) and for F. F. Ingram & Co. (1909-10), prescriptionist in the Geo. B. Evans store (1910-11), and then joined Hoffman-La Roche as Phila. salesman. In 1914 he became sales mgr.; in 1920, gen. mgr. and treas.; in 1928, vice-pres.; in 1936, pres. During World War II Bobst was chmn., N. J. War Finance

On March 30, the grand jury indicted on six counts those connected with the Quinine Convention, all of whom were residents of Holland, excepting Robert H. de Greeff, who pleaded not guilty, furnished \$5,000 bail, and was permitted to go to Holland to explain the situation. Representatives of the cartel came to this country to confer with the Attorney General on the consent decree which had been signed by all of the American firms involved. The Dutch manufacturers, while denying any guilt under the laws of their country and repudiating the jurisdiction of the American court,<sup>48</sup> agreed with the Kina Bureau to sign a consent decree pledging not to engage in activities within the United States which were in conflict with the Sherman, Clayton, and Wilson Acts.<sup>49</sup> This anti-trust suit revealed the extreme difficulty of single-handed action by the United States in controlling international cartels, for the Buramic Sales Agency was shortly established to handle American quinine business, but carefully making all sales outside the jurisdiction of American courts.<sup>50</sup>

The first synthetic substitute for quinine, Plasmochin,\* appeared in Germany in 1924. It was discovered as a result of a systematic hunt for a synthetic antimalarial begun by I.G. in 1920.<sup>51</sup> Although the drug attracted little attention in this country, the Winthrop Chemical Company obtained sole American rights to it in 1926.<sup>52</sup>

Theobromine (3,7-dimethylxanthine), the alkaloid extracted from the cacao bean, was beginning to be rather extensively used in the preparation of synthetic caffeine† (1,3,7-trimethylxanthine), by the simple process of methylation, a rivalry further complicated by the favor which theobromine found among physicians as a substitute for caffeine as a diuretic.<sup>53</sup> Theobromine from cacao waste and caffeine from waste tea leaves had both been prepared in this country since 1907 by the Maywood Chemical Works.<sup>54</sup> The better demand prompted the Monsanto Chemical Works to start production of theobromine in a new, \$150,000 factory built in 1925, at Norfolk, Virginia.<sup>55</sup> In 1928, however, Monsanto closed this plant and bought cheaper theobromine abroad to fill current orders. At the tariff hearings in 1929, when both American producers asked for protection, the Netherlands Chamber

Comm. Today he is pres.-gen. mgr., Wm. R. Warner & Co. and its subsidiaries; advisory trustee of Rutgers U.; and bd. vice-chmn., Am. Cancer Soc.

\* Plasmochin, which was given the nonproprietary name of pamaquine during World War II, is 6-methoxy-8-(1-methyl-4-diethylaminobutylamino)quinoline. It proved to be highly toxic and to have a narrow spread between the maximum tolerated dose and the minimum effective dose. (M. T. Bogert, to author, Oct. 31, 1946.)

† The natural alkaloid was discovered by Woskresensky in 1841. Ripe cacao beans contain from 1.5 to 3% of caffeine which is also found in kola nuts. The quantity of tea waste required to produce a pound of natural caffeine is 55 times the amount of theobromine needed to yield a pound of synthetic caffeine. (See Tariff Comm., *Census of Dyes*, 1929, p. 138.)

of Commerce presented a brief supported by affidavits, indicating that Monsanto had offered to sell 55,000 pounds of theobromine a year for three years, beginning January 1, 1930, at 75 cents a pound, as against the import price of \$1.15 a pound.<sup>56</sup> At the same hearings Dr. Fred W. Russe, appearing for the Mallinckrodt Chemical Works, asked for a compensating duty better to equalize the competition between caffeine and caffeine citrate.<sup>57</sup> Caffeine paid a specific duty of \$1.50 a pound; the citrate paid 25 per cent ad valorem. Since caffeine citrate is made up of practically 54 parts of caffeine and 56 parts of citric acid,\* it was actually cheaper to import the salt than to make it.

Higher standards did not miss the alkaloids, and in 1927 the Contact Committees of the Drug Manufacturers' and the Pharmaceutical Manufacturers' Associations presented additional recommendations covering the maximum and minimum limits of the active ingredients of hypodermic tablets † and methods of assaying them.<sup>58</sup> The Bureau of Chemistry, whose pharmacologist, Dr. James C. Munch, visited leading drug manufacturers to arrange for the cooperation of their laboratories, made an additional study of methods of determining the strength of digitalis.<sup>59</sup>

During the twenties the price of all alkaloids was reduced sharply. The decline was initiated in 1924 by Hoffman-La Roche, which had extended manufacturing operations in this country and which in June announced lower prices for all minor alkaloids. What the trade press characterized as "an alkaloid price war" resulted in bringing the price of atropine sulfate, for example, to \$3 an ounce.<sup>60</sup> During 1928 and 1929 many alkaloid prices recovered, but they remained substantially lower than the quotations of 1922. ‡

Ephedrine was not the only ancient Oriental medicament that profited from American chemical researches. For generations Eastern medical folklore maintained that if a leper could down generous doses of chaulmoogra oil, he was destined to be cured. Subcutaneous injections were adopted in 1899 and the pain of this treatment was mitigated by dilution with olive oil or camphorated oil, and the addition of resorcinol and the local anesthetic, benzocaine. About 1920 A. L. Dean, then professor of chemistry and later president of the University of Hawaii, digested chaulmoogra oil with alcohol and a little sulfuric acid, converting it into the ethyl derivative.<sup>61</sup> The pioneering work<sup>62</sup> on the chemistry of chaulmoogra oil was done in England by another American,

\* The record appears to be in error on these figures, which according to *Merck Index* should be anhyd. caffeine, 50.27%; anhyd. citric acid, 49.73%.

† The items covered were codeine phosphate, pilocarpine hydrochloride, caffeine and sodium benzoate, caffeine, apomorphine hydrochloride, hyoscine hydrobromide, procaine, morphine, atropine, physostigmine sulfate, physostigmine salicylate, and arecoline hydrobromide.

‡ For low-high prices of principal alkaloids, 1922-29, see Appendix IV.

Dr. Frederick B. Power,\* and Roger Adams† of the University of Illinois prepared a number of synthetic compounds closely related chemically to those in chaulmoogra oil, which proved effective in the treatment of leprosy.

Research fellowships were beginning to be very popular with drug manufacturers. A project at the Mellon Institute evolved a novel process for the manufacture of betaine hydrochloride, previously extracted from beet sugar waste, and it was believed that markedly lower costs would develop new uses,<sup>63</sup> which have not materialized. The first two fellowships at the New Jersey College of Pharmacy, both established in 1928, brought interesting results.<sup>64</sup> Under the Johnson & Johnson grant for investigating germicidal agents, Lloyd K. Riggs and Lyman Fonda studied the hydrogen-ion concentration of culture media, developing new methods requiring only minute quantities of both sample and culture. The Merck fellowship for the study of heart stimulants, chiefly of the digitalis group, developed new and more accurate assay methods. In 1924 Drs. E. A. Graham and W. H. Cole of the Washington University Medical School developed tetrabromophenolphthalein, whose sodium compound has become a standard preparation for intravenous injections for X-ray examination of the gall bladder.<sup>65</sup> Mallinckrodt began manufacturing this chemical in 1924.

The common cold, scourge that costs the American people "more than a million man-years of activity annually," inspired Francis P. Garvan, president of the Chemical Foundation, to provide funds for a research of its causes. He announced this at the American Drug Manufacturers' Association convention in 1926 and a committee was appointed to cooperate with the Foundation in formulating plans. On New Year's Day, two years later, Garvan announced the grant to Johns Hopkins of \$195,000, to be spread over five years, for what was to be known as the John J. Abel Fund for Research on the Common Cold.<sup>66</sup>

These more serious scientific activities, the broadening base of drug manufacturing, and the opening of new merchandising outlets, were all reflected in mounting sales values. In the ten years from prewar (1914)

\* Power (1853-1927) graduated from Phila. Coll. Pharm. in 1874 and got his Ph.D. at Strassburg, 1880. Between 1881 and 1892 he taught at the Phila. Coll. Pharm. and U. Wis., when he became dir. lab. of Fritzsche Bros. In 1896 he went to London with the Wellcome Chemical Research Labs., returning to the U. S. in 1916 in charge of the Phytochemical Lab., Bur. Chem. He was repeatedly honored for his researches, winning the Ebert prize of the Am. Pharm. Assoc. 3 times, the Hamburg, and Wellcome, and Flückiger gold medals, and medals and diplomas at the exhibitions held at St. Louis, 1904; Liège, 1905; Milan, 1906; Franco-British Exhibition, 1906; Brussels, 1910; Turin, 1911. For his original experimental work, see *J. Chem. Soc.* 85, 838, 851 (1904); 87, 884 (1905); 91, 557 (1907).

† It was largely for his work on chaulmoogra oil that Adams was awarded the Nichols medal in 1927. For these researches, see *J. Am. Chem. Soc.* 47, 2727 (1925); 48, 1080 (1926).

to the middle of this period (1925), the value of pharmaceutical products grew over \$1,000,000 a month from \$150,000,000 to \$320,000,000.<sup>67</sup> \*

This exuberant growth was met by mergers and expansions of manufacturing capacity. E. R. Squibb & Sons, for example, erected in 1924 a thirteen-story addition to the Brooklyn plant and four years later contracted for a new \$1,000,000 unit there.<sup>68</sup> In 1925 E. R. Squibb & Sons of Canada, Ltd., was organized and two years later a short-lived French subsidiary.<sup>69</sup> In 1929 the company was operating six plants and reported profits of over \$1,500,000, including dividends from subsidiaries.<sup>70</sup> Sharp & Dohme in 1927 surrendered its New Jersey charter, dissolving the Sandee Company (a stockholding corporation) and organizing a Delaware corporation with a capitalization of \$1,000,000.<sup>71</sup> In 1929 the company purchased the pharmaceuticals and biologicals manufacturing firm of H. K. Mulford Company of Philadelphia by exchange of stock, and Sharp & Dohme's corporate structure was again expanded. New stock was issued and \$13,500,000 plus 225,000 common shares were paid to stockholders of the old company.<sup>72</sup> At this time Dr. A. R. L. Dohme became chairman of the board, and A. Homer Smith, president.† Frederick Stearns & Company also centralized its operations by taking over its Canadian subsidiary and 88.7 per cent of the common stock of Nyal Company.<sup>73</sup> Swann-Myers Company of Indianapolis built a \$150,000 plant addition in 1926, and in 1927 G. W. Carnrick Company, a \$40,000 extension of its plant in Newark.<sup>74</sup> Pitman-Moore & Company, a controlling interest in which James E. Bartlett, ‡ formerly president of Parke, Davis & Company, had purchased in 1923, built a new, large office and laboratory building at Indianapolis with refrigerating rooms for the storage of the company's biological products from the Zionville plant.<sup>75</sup> During these years Hoffman-La Roche expanded greatly, purchasing twenty acres at Nutley, New Jersey, where a model plant was occupied in 1929. Here the alkaloids, other fine chemicals,

\* Some of the values of 1925: Druggists' preparations, \$78,813,209; antiseptics, \$13,769,886; disinfectants, \$5,598,048; alkaloids & derivatives, \$5,035,281; deodorants, \$4,335,203; other biologicals, \$3,876,000; serums, \$2,862,411; antitoxins, \$2,573,728; vaccines, \$1,335,184; germicides, \$1,301,149; pharmaceutical metals & salts, \$1,176,193. [See *Drug. Circ.* 71, 160 (1927).]

† Besides Dohme and Smith, the new board, upon which the various banking houses were represented, had the following members: R. H. Cory of Lamot, Corliss & Co.; Chas. D. Dickey of Brown Bros. & Co.; Edwin A. Fish of Chas. D. Barney & Co.; B. H. Griswold, Jr., and Thomas Hildt of Alex. Brown & Sons; C. N. Lauer and Thomas Newhall of Drexell & Co.; Ernst Stauffen and Ernst Stauffen, Jr. [See *Com. Fin. Chron.* 129, 648 (1929).]

‡ After 2 yrs. of special courses at Phila. Coll. Pharm., Bartlett went to Parke, Davis as anal. chem. in 1889 and via purchasing agent, mgr. Chicago branch, supt. of branches, and gen. sales mgr., became pres., resigning in 1921. He became active head of Pitman-Moore 2 yrs. later.

and pharmaceutical specialties of the parent Swiss company were manufactured for the American market.<sup>76</sup>

Another foreign affiliate, Burroughs Wellcome & Company, which had started manufacturing in this country in New York in 1909, registered as a New York corporation with a capitalization of \$1,250,000 in 1925, and the next year moved its manufacturing activities to a ten-acre site in Tuckahoe, New York.<sup>77</sup> A newcomer was the Pyridium Corporation, which incorporated in 1925 to manufacture a urinary dye antiseptic, pyridium (phenyl-azo-diaminopyridine), and its derivatives, and two years later organized Rare Chemicals, Inc. Half of the stock was owned by C. F. Boehringer & Söhne of Mannheim-Waldhof, Germany. Plants of both companies, whose president was William S. Lasdon and for which Merck & Co. were sales agents, were established at Nepera Park, near Yonkers, New York.<sup>78</sup>

The merger movement surged strongest among the proprietary preparations. Outstanding examples were Sterling Products Company, originally built upon Bayer's aspirin, and American Home Products Corporation. Sterling Products took over the important Charles H. Phillips Chemical Company (milk of magnesia) in 1923 and its subsidiary, Household Products, two years later bought the Pepsin Syrup Company for \$5,000,000 largely paid for in stock, and in 1929 "Mum," for which it organized a subsidiary, also invading England by purchase of Scott & Turner, Ltd., manufacturers of "Andrew's Liver Salt."<sup>79</sup> In 1929 Drug, Inc., acquired the Three-in-One Oil Company for 25,000 of its own shares, and the Bristol-Myers Company for 259,707 shares.<sup>80</sup>

The American Home Products Corporation started in 1926 by combining the Wyeth Chemical Company, its affiliate, the Larned Company, the Deshell Laboratories, and Edward Wesley & Company. The following year it bought Bisodol and also acquired the International Chemical Company, Ltd., which gave it a plant in Europe and a place in foreign markets. In 1929 it purchased the Manhattan Medicine Company, Ripans Chemical Company, Bovinine Company, Hubert's Malvina, Inc., and the L. F. Medicine Company.<sup>81</sup> An interesting small merger was the purchase of the Sanitol Chemical Laboratory Company for \$425,000 by William R. Warner & Company.<sup>82</sup>

Commercially considered, the transformation of the old New York jobbing house, McKesson & Robbins, into a chain group was most significant. This innovation in drug trade organization had its inception in the division of the old McKesson & Robbins interests in 1924, when the sons of John McKesson, Irving and Donald,\* took over the New

\* Both Irving, born 1872, and Donald, born 1881, went respectively from Columbia and Yale into the family business, the former into the office and the latter into the plant. Irving has served as a trustee of the N. Y. Coll. Pharm., and Donald as dir., Chem. Alliance, Synth. Org. Chem. Mfrs. Assoc., and Drug & Chem. Club (N. Y.).

York Quinine & Chemical Works, the fine chemical manufacturing branch of the business, while Herbert D. Robbins\* and Saunders Norvell acquired the McKesson & Robbins name and the Norvell Chemical Corporation, which was soon transferred to the Heyden Chemical Company.<sup>83</sup> Management of the N.Y.Q. business, including its plant in Brooklyn, was placed in the hands of Francis J. McDonough, formerly vice-president of McKesson & Robbins and Norvell. The new McKesson & Robbins management promptly expanded into a wholesale chain, purchasing in 1926 Girard & Company of Bridgeport, thus acquiring a plant where manufacturing of pharmaceutical and drug specialties was undertaken on a large scale.<sup>84</sup> After this merger the officers became Robbins, chairman; Norvell, chairman of the executive committee; and Donald Coster of Girard, president. By 1929, by which time both Robbins and Norvell had retired from active management, the company had acquired 28 wholesale drug houses throughout the United States, which prompted the Federal Trade Commission to investigate them under the Clayton Act, but it dropped the case as no "suppression of competition" was found.<sup>85</sup>

In Philadelphia, the nation's original drug capital, two of the oldest jobbing houses merged<sup>86</sup> in 1929 when Smith, Kline & French Company, established in 1841, took over the Valentine H. Smith & Company, established 1830. The latter company had the year before acquired Robert Shoemaker & Company, and in the reorganization the manufacturing departments of all these enterprises were combined in the Smith, Kline & French Laboratories under the same officers and management.† Indicative of the many changes in merchandising was the announcement<sup>87</sup> by Montagu Sterling, head of E. Fougera & Company, importers of French pharmaceutical specialties and perfume ingredients, that in the future the firm would enlarge its manufacturing activities and discontinue the sale of chemicals and raw materials.

In retrospect, these many changes in the commercial phases of the drug industry during the twenties stand out most prominently. Rather than notable technical advances, it was the expansion of the business which brought the United States to the top place as a world producer, consumer, and exporter of all types of medicinal products that marked this decade.

\* Robbins (1862-1947), born in N. Y., educated at Bklyn. Poly. Inst. and Harvard (A.B., 1884), studied chem. under von Hofmann, 1884-85. His entire business career was with McKesson & Robbins and for yrs. he was treas. of the N. Y. Coll. Pharm.

† C. Malhon Kline, chmn. bd.; W. V. Smith, pres.; J. M. Buck, vice-pres.; H. E. Smith, secy.; J. L. McCurdy, treas.



## REFERENCES

1. *J. Am. Pharm. Assoc.* 16, 844 (1927).
2. W. A. Lewis, *Economica* 202 (Nov. 1945); Hotchkiss, *Milestones of Marketing*, pp. 194-96, 200, 275. See also Nystrom, *Economics of Retailing*; Beckman and Nolan, *Chain Store Problem*.
3. *Drug. Circ.* 6 (Mar. 1933).
4. *J. Am. Pharm. Assoc.* 12, 537 (1923).
5. *Drug Chem. Mkts.* 18, 539 (1926).
6. *Ibid.* 17, 1067 (1925).
7. *Drug. Circ.* 70, 300 (1926).
8. *Ibid.* 71, 9, 64 (1927).
9. *Pharm. Era* 59, 2 (1924).
10. *Drug Chem. Mkts.* 16, 582 (1925).
11. *Drug. Circ.* 73, 102 (1929).
12. *Ibid.* 52.
13. *J. Am. Pharm. Assoc.* 18, 531 (1929); 12, 934 (1923).
14. *Ibid.* 13, 574 (1924).
15. *Ibid.* 15, 65 (1926); 16, 95 (1927); 18, 1002 (1929).
16. *Ibid.* 18, 1090 (1929).
17. Food, Drug & Insecticide Admin., *Ann. Rept.* 1928, p. 4.
18. Hearings, May 24, 1926, p. 25.
19. *J. Am. Pharm. Assoc.* 18, 86 (1929).
20. *Ibid.* 16, 595 (1927).
21. Weber, *Food, Drug and Insecticide Administration*, pp. 1, 34.
22. *O.P.D. Repr.* 21 (May 30, 1927); *Chem. Met. Eng.* 35, 318 (1928).
23. *Drug Chem. Mkts.* 12, 461, 603, 1179 (1923).
24. *Ibid.* 16, 411, 435 (1925).
25. *Ibid.* 511; *O.P.D. Repr.* 19 (Feb. 9, 1925).
26. *Drug Chem. Mkts.* 14, 9 (1924).
27. L. Kolb and A. G. DuMez, *Pub. Health Rept. No.* 924 (1924).
28. *Drug Chem. Mkts.* 12, 335 (1923).
29. *Pharm. Era* 58, 538 (1924).
30. Hearings Ways & Means Comm. (House 69:1) on H.R. 11612, May 1926, p. 45.
31. *O.P.D. Repr.* 50 (Apr. 18, 1927); 50 (May 2, 1927); 50 (May 9, 1927); 22 (May 23, 1927); 21 (Aug. 8, 1927); 46 (Oct. 3, 1927); 32 (Oct. 24, 1927); 25 (Mar. 19, 1928); 26 (Apr. 16, 1928).
32. *Ibid.* 63 (May 18, 1925); *Drug Chem. Mkts.* 16, 1495 (1925); *Am. Druggist* 54 (June 1925).
33. Hearings Ways & Means Comm. (House 68:1) on H.R. 7079, Apr. 1924.
34. *J. Am. Pharm. Assoc.* 14, 656 (1925).
35. *Drug Chem. Mkts.* 17, 1407 (1925).
36. J. B. Peterson, *Ind. Eng. Chem.* 20, 388 (1928); *J. Am. Pharm. Assoc.* 15, 509 (1926), 17, 940 (1928); *Drug. Circ.* 60 (Aug. 1932); Chen and Schmidt, *Ephedrine and Related Substances*, pp. 4-5.
37. *Drug. Circ.* 60 (Aug. 1932).
38. *Ibid.*; Chen and Schmidt, *op. cit.*; Stieglitz, *Chemistry in Medicine*, p. 412.
39. Co. memo to author.
40. *Drug. Circ.* 60 (Aug. 1932).
41. Chen and Schmidt, *op. cit.* p. 12; *O.P.D. Repr.* 21 (Nov. 21, 1927).
42. *Drug Chem. Mkts.* 16, 886 (1925).
43. *Ibid.* 10, 25 (1922).
44. *Ibid.* 12, 601 (1923); *O.P.D. Repr.* 17 (Feb. 8, 1932).
45. *O.P.D. Repr.* 21 (Nov. 21, 1927); *Chem. Mkts.* 21, 579 (1927).
46. *Drug Mkts.* 21, 562 (1927).
47. *Ibid.* 22, 327 (1928).
48. *Ibid.* 23, 137 (1928).
49. *O.P.D. Repr.* 17 (Sept. 24, 1928); *Chem. Met. Eng.* 35, 584 (1928).
50. *O.P.D. Repr.* 44 (Feb. 8, 1932).
51. For account of discovery and development, see A. E. Sherndal, *Chem. Eng. News* 21, 1154 (1943).
52. *O.P.D. Repr.* 20 (Oct. 4, 1926).
53. Stieglitz, *op. cit.* p. 534.
54. Levi Cooke, Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 8, 1929, p. 313.
55. J. W. Boyer, *ibid.* p. 239.
56. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929, Sched. 1, June 1930, p. 366.
57. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 7, 1929, p. 21.
58. *Ind. Eng. Chem.* 19, 61 (1927).
59. *O.P.D. Repr.* 42 (May 9, 1927).
60. *Drug Chem. Mkts.* 14, 259 (1924).
61. Dean and R. Wrenshall, *J. Am. Chem. Soc.* 42, 2626 (1920). Stieglitz, *op. cit.* p. 635; *Drug Chem. Mkts.* 10, 409 (1922).
62. *O.P.D. Repr.* 20 (Apr. 4, 1927); D. H

- Killeffer, *Ind. Eng. Chem.* 18, 1043 (1926).
63. *Am. Druggist* 25 (June 1929).
64. *Drug. Circ.* 8 (May 1930).
65. *Pharm. Era* 58, 328 (1924); orig., *J. Am. Med. Assoc.* 82, 613 (1924).
66. *Drug. Circ.* 169 (May 1926); *J. Am. Pharm. Assoc.* 17, 214 (1928); *O.P.D. Repr.* 41 (Apr. 19, 1926), 38A (Jan. 16, 1928).
67. *Drug. Circ.* 71, 932 (1927).
68. *Pharm. Era* 59, 39 (1924); *O.P.D. Repr.* 40 (Jan. 30, 1922).
69. Co. memo to author.
70. *Drug. Circ.* 74, 48 (1930); *Chem. Met. Eng.* 37, 17 (1930).
71. *O.P.D. Repr.* 21 (Jan. 3, 1927); *Drug Mkts.* 20, 23 (1930).
72. *Drug Mkts.* 25, 167 (1929); *Com. Fin. Chron.* 129, 648, 1301 (1930).
73. Co. prospectus, Mar. 31, 1936, p. 3.
74. *Drug Chem. Mkts.* 18, 1281 (1926); *Chem. Met. Eng.* 34, 528 (1927).
75. *Pharm. Era* 68, 354 (1924).
76. *Drug. Circ.* 73, 31 (1929).
77. *J. Am. Pharm. Assoc.* 13, 872 (1924); *Ind. Eng. Chem., News Ed.* 9, 121 (1931).
78. Co. prospectus, June 11, 1937, p. 4.
79. *Drug Chem. Mkts.* 12, 19 (1923), 17, 571 (1925); *Com. Fin. Chron.* 129, 1293 (1929); *Poor's Manual of Industries*, 1930, p. 2385.
80. *Poor's Manual*, *op. cit.* p. 2382.
81. Co. memo to author.
82. *Drug Chem. Mkts.* 10, 335 (1922).
83. *Pharm. Era* 59, 593 (1924); *Drug Chem. Mkts.* 15, 1777 (1924).
84. *Am. Druggist* 53 (Dec. 1926); *Chem. Mkts.* 19, 1081 (1926), 28, 282 (1931).
85. *O.P.D. Repr.* 20 (Dec. 30, 1929); 21 (Aug. 11, 1930).
86. *Drug Mkts.* 24, 581 (1929).
87. *Ibid.* 43.

## Chapter 18

### SCENTS AND FLAVORS: SYNTHETIC AND NATURAL

COSMETIC PRODUCTION REACHES 194 MILLION DOLLARS—HIGHER DUTIES ON AROMATIC CHEMICALS THAN ON AROMATIC MIXTURES HAMPER U. S. MANUFACTURE—CAMPAIGN FOR AMERICAN TOILET GOODS—MONOPOLIES IN MENTHOL, CAMPHOR, AND MUSKS CURBED BY SYNTHETIC PRODUCTS—SACCHARIN APPROVED IN FOODSTUFFS—VANILLIN AND COUMARIN ADVANCE AS FLAVORS—VAN AMERINGEN-HAEBLER AND COLGATE-PALMOLIVE-PET MERGERS.

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**I**N NO YEAR PRIOR TO 1914 did the value of cosmetics made in the United States (excluding soaps) reach a total of \$24,000,000.<sup>1</sup> By 1921 the figure mounted to over \$90,000,000; to \$193,441,000, by 1929.\* America's "beauty bill"—cosmetic sales plus beauty shop services—was said that year to exceed \$400,000,000, a figure that called forth cheers and jeers. There were many reasons for this sudden great growth.

A change in attitude towards cosmetics was the most important of these. Rouge, lipstick, and nail enamel, branded as the badge of Jezebel during the Gay Nineties, came during the Booming Twenties to be considered perfectly legitimate, sometimes imperative, beauty aids, an impressive example in our time of the force exerted upon economics by social customs. This seemingly superficial change in fashion, which so stimulated a large sector of the chemical and drug industry, had behind it powerful forces. It was an indicator of the profound change in American philosophical and religious attitudes that had been shifted by the upheaval of the First World War and which were further shaken by the Prohibition experiment and the openhanded prosperity of the post-war decade.

While we recognize in passing these deep-rooted causes, it is particularly noteworthy in economic history that the increased use of cosmetics by American women coincided with the perfection of modern advertising techniques. The simple, straightforward announcement of goods for sale was replaced by subtle, psychological appeals to pride,

\* Vital statistics of the perfumery and cosmetics industry are in Appendix II & XXXIV. See also O. Wilson, *Ind. Eng. Chem.* 19, 346 (1927); Haynes, *This Chemical Age*, Chap. 6; Sagarin, *Science and Art of Perfumery*, Chap. 16.



ERIC C. KUNZ



*Drug & Cosmetic Industry*

WILLIAM. T. HAEBLER



*Drug & Cosmetic Industry*

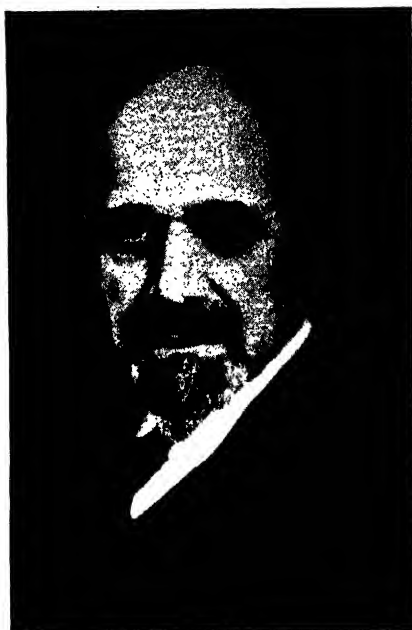
A. L. VAN AMERINGEN



CHARLES A. SWAN



A. W. PEET

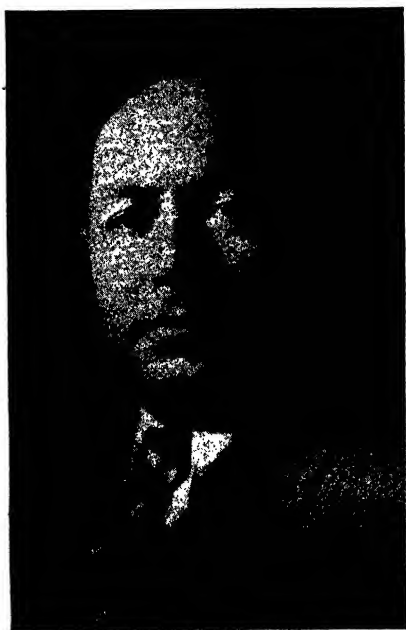


*Chemical Industries*

SAMUEL ISERMANN



CHARLES S. PEARCE



*Drug & Cosmetic Industry*

JOSEPH FELTON

vanity, and even fear. Testimonials signed by Mary Garden, Julia Sanderson, Jane Cowl, and other bright names of the stage, screen, and society became a favorite theme. Beauty culture was emphasized, and Palmolive had a whole series of advertisements featuring photographs of famous beauty specialists and quoting their professional advice. The appeal to Science (always with a capital "S") made its first appearance. Woodbury Facial Soap talked glibly of "desquamation," carefully defined as "the medical term for invisible skin peeling."<sup>2</sup>

Advertising copy not only became more frank and persuasive, but its purely mechanical features—layout, art work, the use of colors—were more esthetically appealing. The media of advertising also improved and multiplied, especially the women's magazines, and cosmetic advertisements which before the war had occupied two-inch, single-column spaces, blossomed forth in full-page display, vying with the automobile, the biggest space-buyer of the period. The sponsored radio program appeared, and perfume and toilet goods manufacturers were among the first to realize its possibilities. During the twenties, the oldest radio program of all, "Amos and Andy," was sponsored by Pepsodent tooth paste.

The full benefits of this luxurious growth of the perfume business did not immediately come to the American makers of the raw materials. Domestic manufacturers of the more expensive perfumes had at this time to concede the better part of their market to imported wares. But they were fighting a winning battle against their foreign competitors and in the lower-price brackets American cosmetics were supreme. Advertising was a great help in this competition, and during the war, when imported goods were cut off, Colgate conducted one of the then-popular blindfold tests—three Colgate perfumes, three imported, none labeled—in which a jury of over a hundred women disproved the supposed superiority of imported "odeurs."

More serious than the lag in the sale of domestic perfumery was a flaw in existing tariff law which handicapped the growth of the synthetic aromatic chemical industry in this country. That law, written to provide adequate protection for coal-tar products, contained a damaging exception which permitted the importation of mixtures of synthetic and natural aromatic compounds at rates markedly lower than those provided for the chemicals themselves. Furthermore, synthetic aromatics were omitted from the labeling clause, and through these two loopholes foreign manufacturers brought in compounds of scents and flavors at prices which were better than competitive.<sup>3</sup>

This flaw in the Fordney-McCumber Tariff hurt American makers in two ways. It hamstrung manufacture of synthetic organic aromatics; it encouraged foreign perfumery makers to import blended ingredients

and to combine and package them in this country. American manufacturers of toilet articles complained that the imports of finished preparations fell off more than \$3,000,000 in 1923, the first year after this new tariff was adopted, and that this represented a saving of \$500,000 in tariff duties.<sup>4</sup> Though both groups protested the identical provisions of the Fordney-McCumber Tariff, the interests of American manufacturers of synthetic aromatic raw materials and of finished cosmetics collided violently and each suggested diametrically opposite remedies. This clash enlivened the dinner of the Perfumery, Soap & Allied Industries at the Hotel Astor, New York City, on March 28, 1923. This local organization had appointed a Tariff Committee composed of Warren Burns of Morana, Russell B. Stoddard of Ungerer & Company, and Victor Vivaudou, head of the perfumery house. They recommended an appeal to Washington through the American Manufacturers of Toilet Articles for a 50 per cent reduction in the duties on the raw materials of cosmetics, in accordance with the flexible provision of the Act. Dr. S. Isermann of Van Dyk & Company and Dr. L. Jenkel of Denney & Denney fought back bitterly in defense of the duty on raw materials, landing some sarcastic blows on the selfish inconsistency of the highly protected perfumers.<sup>5</sup>

These cross-purposes of self-interest could not be reconciled. However, the two groups did join heartily in a campaign against the common contender, the foreign manufacturers. This campaign led to the promotion of the first Perfumery Show, held in New York in the 71st Regiment Armory, April 5 to 11, 1923, where 75 American makers of toilet preparations exhibited.<sup>6</sup>

The American Manufacturers of Toilet Articles, which sponsored this exposition, was one of the most active trade associations. In 1924 it placed \$10,000 at the disposal of G. A. Russell, biologist of the U. S. Department of Agriculture, to be devoted to research and the cooperative cultivation of floral raw materials in this country. Due largely to its efforts, a course in perfume chemistry was established at the College of Pharmacy, Columbia University, in 1925.<sup>7</sup> At the 1929 meeting, the association approved a "perfumopoeia," and to this end appointed a committee to prepare a set of technical monographs on all important perfume raw materials, which would give the history and sources, physical and chemical properties, tests of identity, checks on purity, and the general and specific uses.<sup>8</sup> At the same time it was announced that arrangements had been made for a search of the literature at the Columbia University Library covering the pharmaceutical properties of essential oils and other cosmetic materials, a bibliography harking forward to the exploitation of medicinal properties in cosmetics, which became unusually popular during the 1930's.

Ever since the great tariff authority, F. W. Taussig, forecast \* that no tariff protection could establish a coal-tar industry in this country because American chemists and industrialists lacked the patience and skill to manufacture successfully a long line of complex, organic compounds sold in comparatively small quantities, his well-worded argument has been the pet alibi for any gaps in these products. This handy, but not-too-valid excuse was made for the slow and faltering production of synthetic aromatics in this country.† Neither technical adroitness nor managerial perseverance was lacking, but there was little encouragement to embark in this field of chemical manufacturing.

American manufacturers of toilet goods bewailed the preference of American women for imported perfumeries, blaming a national inferiority complex in colonial days, nevertheless they themselves frequently displayed the same provincialism and bought imported ingredients even when American equivalents were available. In this chilly atmosphere there was little incentive to invade a limited market strongly held by experienced European competitors, chiefly French and Swiss, through the gaps in the coal-tar tariff duties. This branch of the industry grew slowly, but it was able to make substantial progress thanks chiefly to a few persistent enthusiasts who maintained the toehold that they had won during the war: ‡ Dr. Samuel Isermann of Van Dyk, who helped so generously in the tariff fight; Burton T. Bush, a stormy, aggressive friend of the American industry; von Isakovics and Dodge and Felton and the three Frieses, while Dr. Martin Ittner of Colgate was almost alone among the manufacturing perfumers in his support of American-made aromatics.

The annual lists of synthetic aromatics produced for the first time in the United States, published in the *Census of Dyes*, record steady progress. During the twenties such products as dibutyl and diamyl phthalate, methyl acetophenone, amyl heptoate, ethyl maleate, myristate, and ricinoleate, furfuryl acetate, benzyl succinate, butylphenyl

\* See Vol. III, p. 269.

† See R. Trubek, *Chem. Met. Eng.* 41, 199 (1934), which, in my opinion, overemphasizes the American flare for continuous, large-scale production and impatience with batch operations requiring meticulous control and tedious recycling and underestimates the economic factors. (W. H.)

‡ Edward Sagarin of Givaudan-Delawanna points out that the growth of some companies in the industry was furthered by the support given to their American affiliates by European firms with great experience in this field. Writing of his company, he says, "L. Givaudan & Cie of Switzerland gave to its American branch not only its investment and experience, but continuous technical and other aid in purchasing, manufacturing, and selling, and particularly in financial support of expansion." Chiris gave to its American branch and Schimmel to Fritzsche Brothers the same sort of sincere cooperation, but understandably enough the policy of most of the European companies was not to help build up the aromatic chemical industry in this country and most American firms did not have this sort of assistance. (W. H.)



acetate, *p*-cresol methyl ether, phenylethyl propionate, and many others appeared for the first time.<sup>9</sup> The Kessler Chemical Corporation, Fries & Fries, U. S. Industrial Chemical Company, Synfleur Scientific Laboratories, Burton T. Bush, Inc., and the Felton Chemical Company appear repeatedly in these annals. But the outstanding accomplishment of the twenties in this field was the American production of synthetic menthol, synthetic camphor, and artificial musks.

Like camphor, menthol was a Japanese monopoly. In both economics played as important a part as did chemistry in the development of the synthetic rival which replaced the natural material. After the Japanese earthquake of 1923 the price of menthol\* advanced sharply, and one of the big Japanese trading houses, anticipating a decline, offered large quantities in this country for future delivery at prices well below the current quotations. The two leading Japanese firms, plotting to trap the short-seller, cornered the market, and the price of menthol remained abnormally high.<sup>10</sup> This stimulated prospective competition on three fronts: preparation of menthol from American mint; a world-wide search for other varieties of mint; and finally, the synthesis of menthol.

American peppermint oil, from mint grown chiefly in Michigan, had long been a thoroughly commercial proposition, one of the few essential oils produced in this country. By 1924 American menthol from this source was on the market from Dodge & Olcott, followed promptly by the Rhodia Chemical Company, and a little later by the Orbis Products Trading Company which became the largest American manufacturer. The combined output of these three that year was 200 cases monthly, which in spite of the high price of American peppermint oil, sold materially below Japanese menthol.<sup>11</sup> Having since 1921 carried on extensive experimental cultivation of Japanese mint under the direction of G. A. Russell, in cooperation with the Department of Agriculture, Vick in 1925 began production of natural menthol.<sup>12</sup> The growing experiments continued until 1929 in Michigan, in the old mint-growing sections of New York State and Indiana, in North Carolina, Florida, and California, and over \$60,000 was spent in an unsuccessful attempt to cultivate the *arvensis* variety in the United States.<sup>13</sup> Between 1926 and 1930 some 500 acres of Japanese mint were grown in the San Joaquin Valley by the members of the California Menthol Growers' Association and shipped to Burbank for distillation.<sup>14</sup> Though 12,000 acres would have been needed to satisfy domestic consumption, high labor costs once again made this tempting drug-growing experiment

\* Menthol ( $C_{10}H_{19}OH$ ) is a terpene alcohol found in many essential oils, but commercially obtained by freezing mint oil, the chief commercial source being from the Japanese mint, *Mentha arvensis*. It is closely related to thymol in thyme oil, from which it can be prepared by hydrogenation. [See A. L. Barney and H. B. Hass, *Ind. Eng. Chem.* 36, 85 (1944).]

uneconomic. In Kenya, East Africa, where in 1926 J. L. Green found a native plant of the mint family yielding both thymol and camphor, the project was more successful, but again only for a short time.<sup>15</sup>

Efforts to break the artificially sustained price of natural menthol through the synthetic were more successful. In December 1922 synthetic menthol first appeared in the American market, offered by a British firm, Howard & Sons, Ltd.<sup>16</sup> The price was high, though lower than for the mint oil product. By 1923, however, the price in New York had been reduced to \$9 a pound, compared with \$13 for the natural material. From that date Japanese quotations continued steadily to decline, and as Dr. Herty pointed out,<sup>17</sup> once again a synthetic had assumed control over the monopoly market of its natural competitor. In 1924 the New York Quinine & Chemical Works acquired American rights to the Howard process and began production in its Brooklyn plant, marketing this isomenthol under the trade name of Menthol-Y.<sup>18</sup> Acceptance of the new synthetic was delayed in medical circles because of its optical inactivity, but experiments continued and in 1928 Fritzsche Brothers offered here the more active levorotatory form, perfected in Germany by Schimmel & Company.<sup>19</sup> The 11th Revision of the U. S. Pharmacopoeia accepted the optically active synthetic product; the inactive form was accepted in the 8th Supplement to U.S.P. XII and in U.S.P. XIII.

Thymol, menthol's chemical kinsman, was also produced in this country during the twenties by the Orbis Products Trading Company\* from imported Australian eucalyptus.<sup>20</sup> In 1923 the Bureau of Chemistry took out a public patent for the preparation of synthetic thymol from cymene,<sup>21</sup> and the more familiar synthesis from *m*-cresol reacted with isopropyl chloride by means of the Friedel-Crafts reaction was also introduced by Givaudan-Delawanna. Thymol's mold-resistant property attracted great attention at the time, and a novel application was discovered by Albert B. Newman,† professor of chemical engineering at Cooper Union, a protective paraffin coating for oil paints containing 2 per cent thymol.<sup>22</sup>

Due to its inability to compete with Formosan camphor without tariff protection, American synthetic camphor entered into a quiet period of gestation following World War I. Domestic production disappeared,

\* Orbis' interest in menthol extended to thymol, and in 1928 the company acquired an improved process (R. Wotherspoon, U. S. Pat. 1,839,288) for the production of hydrogenated thymolic ketones. [See *Drug Cosmetic Ind.* 30, 284 (1932).]

† Before he began teaching in 1928, Newman had been with Corn Products Refining, National Zinc, and American Metal; works mgr. for Monsanto, 1918-19; gen. mgr., Thermo Chemical, 1920-25; and chem. engr., General Chemical, 1927-28. He was born in Toronto, May 3, 1888, and educated at U. Mich., A.B., 1910; Ch.E., 1911; M.S., 1926; Ph.D., 1928. Newman has been prof. chem. eng. at C. C. N. Y. since 1938 and dean of tech. sch. since 1941.

but in the laboratories work went forward improving the process in economy of operation and purity of its product.<sup>23</sup> In 1922 it was reported that Monsanto had purchased a German process, but the project was abandoned.<sup>24</sup> At Belleville, New Jersey, a stockjobbing scheme, the Syncho Products Corporation, went into a receivership with \$40,000 liabilities and no cash assets in 1927.<sup>25</sup> Out of its ashes rose a more serious effort, the Belle Chemical Company, organized by Jacob V. Smeaton, president of the S. M. Birch Lumber Company; S. Lindsley, president of the National Carbonic Gas Company; and E. F. L. Lotte, general manager of the National Silk Dyeing Company, with C. A. Bianchi as active general manager. Two years' research with Dr. H. P. Bassett of the chemical consulting firm of Meigs, Bassett & Slaughter justified the building of a commercial plant with an initial production of from 500 to 1,000 pounds a day.<sup>26</sup> This operation was technically practical, but it proved to be commercially infeasible. Meanwhile du Pont and Newport continued their researches which were combined after 1931, when du Pont bought the Newport coal-tar business.

Up to 1930 it was estimated<sup>27</sup> that some \$3,000,000 had been spent by various American enterprises in the as yet abortive development of synthetic camphor, but the stage was being set for the final successful appearance of an American-made product. A du Pont synthetic camphor plant had stood unused for ten years, but demands in this country were growing. Synthetic camphor, regarded suspiciously at first by consumers, was accepted especially in the important plastics industry, and safety glass was being manufactured with a "sandwich" of Celluloid. Between 1922 and 1927, American consumption of camphor almost doubled, from 3,264,035 to 6,104,349 pounds of which 2,933,784 were imported, synthetic material.<sup>28</sup> The increase in synthetic importations from zero in 1922 testified to the breaking of the Japanese camphor monopoly.

In 1923 the Germans\* announced two-fold progress: a cheaper process and a product suitable for medicinal uses.<sup>29</sup> That year the Japanese camphor monopoly, which since 1903 had ruled the market with arbitrary selfishness, recognized the force of synthetic competition when the Governor General of Taiwan reduced the price paid by the Bureau of Monopolies to the Taiwan Camphor Producing Company about 25 per cent on all grades, effective May 1, 1926.<sup>30</sup> Sixty days later export prices were lowered proportionately. German prices of synthetic at once dropped. January 1, 1927, and again in August of that year,

\* Principal German producers of synthetic camphor during 1920's were Chemische Fabrik auf Aktien vorm. E. Schering of Eberswalde and the Rheinische Kampfer u. Celluloid Fabrik of Dusseldorff-Oberkassel. [See *Drug Chem. Mkts.* 18, 90 (1926).]

further price reductions were forced upon the monopoly. With each cut in the export price there was a corresponding reduction in the price to the producer. This was passed on by reducing wages and discharging workers in the camphor forests. The critical point was reached in 1926 when the Government eliminated from the budget for one year, beginning April 1, any item of revenue from the camphor monopoly; clamped a strict censorship upon all statistics; \* restricted production; decided to sell only refined camphor and its by-products.

While effective American production of camphor did not come until the early 1930's, we did achieve independence through synthetics of another important Oriental monopoly. Musk xylene, musk ketone, and musk ambrette, the three chief substitutes † for the great natural fixative of perfumes, were all produced in this country during the 1920's.<sup>31</sup> Commercially this was an important triumph with significant psychological results. Actual production of these necessary ingredients in this country did much to convince the American perfumers and cosmetic manufacturers that American-made synthetic aromatics had arrived and were here to stay.

Domestic establishments of these products brought numerous changes. In November 1923 the energetic American manager of the old French essential oil house, Antoine Chiris of Grasse, France, negotiated the purchase of the aromatic chemical plant which the French company had built in 1914 at Delawanna, New Jersey, and in February 1924 organized Burton T. Bush, Inc., which took over this plant and since that date has operated it with many additions and improvements. The Swiss firm of L. Givaudan et Cie in 1924 purchased a third interest in this plant and later became sole owner. In 1926 a sales company to handle all the products of this plant was organized under the name of Givaudan-Delawanna, Inc.<sup>32</sup> That year, also, Bush withdrew and formed Bush Aromatics, Inc., at which time Dr. Eric C. Kunz ‡ became vice-president, L. Givaudan succeeding Bush as president. The active management of the plant remained in the hands of Martin Szamatolski. §

\* Throughout the 26 yrs. of the Govt. monopoly, to Mar. 31, 1925, average yearly production of crude camphor was 4,379,541 lb.; of camphor oil, 6,014,661 lb.

† For a good review of the history and chemistry of the various synthetic musks, see *Givaudanian* Feb., Mar. 1944.

‡ Born in Switzerland, 1884, and educated at U. Zurich, Kunz had been chem. with Givaudan before being brought to the U. S. in 1915, by Dr. S. Isermann. He was later chem. for the United Piece Dye Works which during the war undertook to make dyes for its own needs. From 1919-25 he was asst. dir. sales of the du Pont Dyestuff Dept. and served as a tech. advisor at the Paris Peace Conference, 1919.

§ Starting as a color chemist, Szamatolski originated the pigments para red, U. S. toners, and sun red; engaged as an aromatic chemist, he developed improved processes for terpineol, phenylethyl alcohol, and artificial musks. He was educated at U. Berlin, came to the U. S. in 1893, was 8 yrs. with Harrison Bros. & Co., pres., Standard Chem-

Various reorganizations involved other personnel changes of well-known men in the aromatics field. In 1924, for example, Milton Seeley, chemist at the Delawanna factory, established himself as Seeley & Company, specializing in oleoresins, fruit extracts, vanilla and vanillin compounds. When Bush withdrew from Chiris, his place as American manager was taken by Charles A. Swan.\*

The Felton Chemical Company, which under the management of Dr. and Mrs. Felton† and Albert Albek contributed many new aromatic products to American production during the 1920's, built a new plant in Brooklyn in 1928.<sup>33</sup> The characteristic evidence of progress at this time was the merger. The Norda Essential Oil & Chemical Company in 1929 bought the business of Louis A. Van Dyk.<sup>34</sup> The Rhodia Chemical Company, American representatives of the Société Chimique des Usines du Rhône and Poulenc Frères, which began manufacturing geraniol, citronellal, citronellol, linalool, rhodinol, and other aromatics at a plant in New Jersey in 1927, was taken over in 1929 by the Newport Chemical Company.<sup>35</sup>

An outstanding consolidation was that of van Ameringen and Morana, which resulted in the formation of the new van Ameringen-Haebler.<sup>36</sup> Morana brought to the combination a plant in Elizabeth, New Jersey, and the American sales agency of Haarmann & Reimer Chemische Fabrik.‡ Van Ameringen had been producing aromatic chemicals and flavoring materials at Orange, New Jersey. The prime movers and chief stockholders were A. L. van Ameringen, § president, and Dr. William T. Haebler, treasurer. An old German chemical manufacturer, Schering-Kahlbaum A.-G. of Berlin,<sup>37</sup> whose importations of synthetic camphor, thymol, menthol, terpineol, and mustard oil had previously been handled by Carl B. Peters, incorporated its own American company in 1929 as the Schering Corporation, whose business in the passing of the years has become less aromatic and more pharmaceutical.

A notable merger in the cosmetic manufacturing industry was the

ical Co. many yrs., and with Givaudan-Delawanna from 1924 to 1938, when he retired to his farm, Hendersonville, N. C., where he died, July 28, 1940.

\* Swan had been with Chiris since 1898 and was works mgr., 1919-24, when he became vice-pres. and 3 yrs. later pres. He was born in N. Y. City, 1883, and attended Pratt Inst. Since 1933 Swan has been secy., Aromatic Products, Inc.

† Joseph Felton, born in Warsaw and educated at U. Breslau, came to U. S. in 1919 as research chem. of Van Dyk & Co., married Sophie Schulman of Bklyn., N. Y., in 1921. They established the Felton Chemical Co. in 1923.

‡ One of the oldest, most distinguished aromatic chemical firms in the world; established 1874; pioneers in commercial production of vanillin and ionone.

§ Born in Rotterdam, 1890, van Ameringen came to U. S. in 1917, as sales agent for several Dutch concerns. Dr. Haebler, born in N. Y. City, 1900, earned his B.S. at Mass. Inst. Tech., 1922, and Ph.D. at Zurich, 1925. Associated with them as directors were H. F. Croen, W. A. Seltmann, Henry Pfaltz, August Merz, F. J. Lynch, P. P. Fallon, C. Schaezter, T. Haebler, and John F. Condon.

Colgate-Palmolive-Peet Company, bringing together in 1928 three of the oldest companies: Colgate, which had been continuously in the same family since its founding in 1806; the Palmolive Company of Chicago, established 1864; and Peet Brothers of Kansas City which began business in 1872. Palmolive and Peet had already combined in January 1926,<sup>38</sup> and a year later Colgate & Company purchased the Pompeian Manufacturing Company,\* makers of massage cream.<sup>39</sup> The combined assets of the amalgamated companies were estimated to be some \$60,000,000, and gross sales of 1927 were upward of \$100,000,000.<sup>40</sup> All three interests were represented among the active executives: Sidney M. Colgate, chairman of the board; Charles S. Pearce,† president and general manager; and A. W. Peet, chairman of the executive committee. The finance committee was headed by Russell Colgate; Felix Lowy was in charge of sales and advertising; and N. N. Dalton, vice-president in charge of production.<sup>41</sup>

One of the fast-growing proprietary houses, the American Home Products Corporation, entered cosmetics in 1927 by acquiring the Oxzyn Company and its subsidiary, the Heather Company.<sup>42</sup> Oxzyn was at this time the only manufacturer of rouge by the wet process and a pioneer manufacturer of lipstick. A year later American Home Products moved further into toilet goods by purchasing Kolynos Company, manufacturers of the dentifrice perfected by its founder, Dr. Newell Sill Jenkins.<sup>43</sup> In the current trend of diversification was the purchase of the Melba Manufacturing Company for \$2,500,000 by D. A. Schulte, head of the cigar chain,<sup>44</sup> and of Amolin by the Norwich Pharmacal Company.<sup>45</sup>

In the closely allied essential oil and crude drug trades there were numerous changes but no conspicuous amalgamations. Closest to a merger was the purchase of the crude drug department of the wholesale house of Smith, Kline & French Company by S. P. Penick & Company.<sup>46</sup> After the dissolution of the old firm of Rockhill & Vietor, its essential oil business was divided. In New York, the former manager of this department, Peter R. Dreyer,‡ continued as P. R. Dreyer, Inc., while the Chicago partner, Frank Z. Woods,§ also carried on under his own

\* The formula and a new process of manufacture were developed by Fred W. Stecher, then clerk in a Cleveland drugstore. The product was put on the market in 1901 and in 1905 the Pompeian Mfg. Co. was incorporated. Stecher was active head till his death in 1916, when Otto F. Leopold became pres.

† Bd. chmn. since 1932, Pearce studied law at U. Wis. (LL.B. 1903). In 1935 he became head of bd. of International Cellucotton Products Co.

‡ Pres. also of Bertrand Freres, Inc., Dreyer, who was born in Denmark, 1868, was with Stanley Jordan Co. and Ungerer & Co. before joining Rockhill & Vietor in 1918.

§ A Canadian by birth, Woods was for yrs. Chicago representative of Rockhill & Vietor, J. L. Hopkins & Co., Allaire Woodward & Co. (crude drugs), and Federal Products Co. (alcohol).

name. A similar change, also in Chicago, was the purchase by A. C. Drury of the essential oil department of M. L. Barrett & Company.<sup>47</sup> Drury had started business as one of the Barrett salesmen and in 1916 branched out for himself, later becoming a salesman for Rockhill & Vietor and serving during the war in the Medical Department of the Army.

In New York William G. and Frederick H. Ungerer\* celebrated in 1925 the 60th anniversary of the founding of Ungerer & Company by their father, William P. Ungerer, in Rochester, New York.<sup>48</sup> The following year, Dodge & Olcott Company, importers of essential oils and perfumery raw materials that trace back to the business of Robert Bach in 1798, underwent a change of personnel when the veteran Christian Beilstein resigned and retired.<sup>49</sup> Francis H. Sloan, president, became chairman of the board; Frank Dodge moved from treasurer to president; Russell R. Sloan, from secretary to vice-president; Harry Howe, from general manager to secretary; while J. Fowler Pound, the manager of the Philadelphia office, became vice-president. The Stallman crude drug business moved into the third generation of family control on the death of Arthur C. Stallman, February 8, 1923.<sup>50</sup> A son of John H. Stallman of Stallman & Fulton, he married a sister of the Ungerer brothers, and his son, F. L. Stallman, took over, forming in 1926 a partnership with G. M. Diehlmann.

While the synthetic aromatic chemical industry was laboriously digging a broader foundation, the production of vanillin and saccharin enjoyed a boom. The powerful, artificial sweetening agent overcame persistent opposition to its use in foodstuffs by Harvey Wiley and other enforcement officials of the Pure Food and Drugs Act and was cleared in court in 1925. The Government suit against the Monsanto Chemical Works, after five years' bitter litigation during which, in 1920 and 1924, there were two jury disagreements, and was finally dismissed in 1925.<sup>51</sup>

Along with citric acid, camphor, and thymol, vanillin made an impressive display of the economic prowess of synthetic competition. As in the other instances, the natural competitor became vulnerable because of its violent price fluctuations. Short crops from 1921 to 1924 shoved up vanilla bean prices from an average of \$2.50 a pound to the record of \$9.00. At the same time the price of vanillin was reduced from 60 cents to 43 cents an ounce. Since synthetic vanillin is chemically identical with the principal constituent in the natural flavoring agent and

\* Wm. G., born in Rochester, 1868, and educated in Paris, became the first American to serve as apprentice in French perfume materials plants. He founded *Am. Perfumer* and was with Colgate till his father's death in 1901 when he joined his brother in Ungerer & Co. Frederick H. was born in Jersey City and educated at Stevens Inst. Tech. and Packard Business Coll.

a pound of the chemical is equivalent in flavoring power to 175 pounds of natural vanilla pods, at this peak price the cost differential in terms of flavoring stood at \$7 a pound for vanillin against \$1,500 for beans.<sup>52</sup>

The high price of vanilla beans had two inevitable results. In Mexico and Madagascar it encouraged the planting of many more acres of vanilla vines. In the United States it drove industrial users of the vanilla flavor—bakers, confectioners, ice-cream makers, cigarette manufacturers—to adopt vanillin.

The famine price of beans had another not unusual effect. Noting the flourishing prosperity of the vanilla planters, the Mexican Government replaced the old tax on the gathering of beans with a new one, twice as heavy, collected on the cured bean. Politically, this seemed very clever. It doubled the revenue and since the beans, grown and harvested by peon labor, are cured off the plantation at central stations and stored in warehouses, the collection was simpler and surer. Economically, however, the move was stupid. It doubled the fixed charge on the cured product from 11½ cents to 23 cents a pound,<sup>53</sup> presenting vanillin with what was in effect a comfortable subsidy.

Three years later, when new vines on the extended plantations came into bearing, the supply of vanilla beans increased beyond demand. The price slumped to a point where it no longer covered the cost of curing and the taxes. In the principal growing centers all over the world the plants, which require considerable cultivation and skillful pruning, were neglected. Then the price rose again, and the vicious cycle was initiated all over again.

Vanillin prices were reacting simultaneously to interrelated causes. Industrial users of vanilla flavoring, having once tried the synthetic, quickly came to like it. It was always available and at a steady price. Its uniformity and purity and strength made it not only cheaper to use but much more convenient in large-scale industrial operations. They followed a rule as inviolate as the laws of the Medes and the Persians, which Biblical authority declares "changeth not," namely that once an industrial consumer adopts a synthetic product, he never returns to the natural material.

During 1926 and 1927 the sales of vanillin and of coumarin\* grew from ounces to pounds,<sup>54</sup> and continued to grow. Makers of both these vanilla substitutes, which at the time included Monsanto Chemical Works, Fries Brothers, Fries & Fries, the Maywood Chemical Works, the Verona Chemical Company, Burton T. Bush, Inc., and Merck & Co.,

\* Called also Tonka bean camphor and coumaric anhydride ( $C_9H_6O_2$ ); first isolated by Vogel in 1813; synthesized from salicylaldehyde and acetic anhydride in the presence of sodium acetate; widely used in synthetic vanilla-flavor blends, and as an extender in the natural extract.



all increased their output and as of January 1, 1926, the Commonwealth Chemical Corporation, which at this time became the Commonwealth Chemical Division of the Mathieson Alkali Works, added vanillin to its list of aromatic synthetics.<sup>55</sup> In announcing a price reduction on coumarin, Monsanto added significantly that its quotation was less than half the price 30 years ago, before coumarin had been synthesized from coal tar, and but 16 per cent above the prewar level, while the average wholesale commodity price of 1927 was 68 per cent above prewar level.<sup>56</sup> Forecasting the future, when vanillin from coal tar and cloves was to meet cheaper vanillin from sulfite pulp wastes, Charles Pfizer & Company in 1929 put on the market, under the trade name Vanethal, ethyl vanillin, three times as strong and more pleasantly fragrant than vanillin.<sup>57</sup>

## REFERENCES

1. J. Thompson, *Am. Perfumer* 27 (July 1940).
2. *Ibid.*
3. C. H. Herty, *Ind. Eng. Chem.* 18, 1025 (1926).
4. *Pharm. Era* 58, 397 (1924).
5. *Drug Chem. Mkts.* 12, 861 (1923).
6. *Ibid.* 921.
7. R. Glenk, *J. Am. Pharm. Assoc.* 13, 913 (1924).
8. *Drug. Circ.* 22 (May 1929).
9. Tariff Comm., *Census of Dyes, 1924*, pp. 64, 122; 1925, p. 58; 1926, p. 54.
10. D. H. Killeffer, *Ind. Eng. Chem.* 16, 995 (1924).
11. *Am. Perfumer* 19, 100 (1924).
12. *Ind. Eng. Chem., News Ed.* 11 (Jan. 10, 1925).
13. Hearings Finance Comm. (S. 71:1) on Tariff Act of 1929, Sched. 1, June 1929, p. 213.
14. I. Benney, *Drug Cosmetic Ind.* 40, 65 (1937).
15. E. G. Thomssen, *ibid.* 43, 546 (1938).
16. *O.P.D. Repr.* 19 (Nov. 17, 1923); *Drug. Circ.* 67, 502 (1923).
17. Herty, *op. cit.*
18. Tariff Comm., *Census of Dyes, 1924*, p. 124; *Ind. Eng. Chem.* 17, 362 (1925); *Drug Chem. Mkts.* 16, 659 (1925).
19. *Drug Mkts.* 22, 43 (1928).
20. L. Cooke, Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 8, 1929, p. 314.
21. *Am. Druggist* 41 (Mar. 1923).
22. *O.P.D. Repr.* 58 (Nov. 25, 1929).
23. I. Gubelmann and H. W. Elley, *Ind. Eng. Chem.* 26, 589 (1934).
24. Tariff Comm., *Synthetic Camphor*, Ser. 2, Rept. No. 104, p. 2.
25. *O.P.D. Repr.* 57 (Oct. 24, 1927).
26. *Ibid.* 21 (Nov. 25, 1929); *Chem. Mkts.* 25, 629 (1929).
27. Tariff Comm., *Synthetic Camphor*, *op. cit.*
28. *Chem. Met. Eng.* 35, 449 (1928).
29. *Drug Chem. Mkts.* 12, 1305 (1923); *Drug. Circ.* 152 (Apr. 1923); *Drug Mkts.* 20, 313 (1927).
30. *Chem. Met. Eng.* 35, 448 (1928).
31. F. Talbot and W. N. Watson, *Ind. Eng. Chem.* 21, 10 (1929).
32. E. Sagarin, to author, Dec. 3, 1946; *Pharm. Era* 59, 238 (1924).
33. *Am. Perfumer* 22, 663 (1928); 23, 99 (1928).
34. *Drug Mkts.* 24, 371 (1929).
35. *Ibid.* 20, 24 (1927); *Chem. Mkts.* 25, 65 (1929).
36. *Chem. Mkts.* 24, 73 (1929); *Drug Mkts.* 20, 440 (1927), 24, 583 (1929).
37. *Drug Mkts.* 24, 54 (1929); *Chem. Mkts.* 24, 73, 291 (1929).
38. *Am. Perfumer* 23, 307 (1928).
39. *Ibid.* 22, 79 (1927).
40. *Ibid.* 23, 307 (1928); *Drug. Circ.* 42 (Aug. 1928).
41. *Am. Perfumer* 23, 372 (1928).
42. Co. memo to author.
43. *Ibid.*
44. *J. Am. Pharm. Assoc.* 16, 97 (1927).
45. *Am. Perfumer* 23, 600 (1928).

46. *Drug Chem. Mkts.* 10, 799 (1922).
47. *Ibid.* 793, 18, 1021 (1926); I. P. Mac-Nair, to author, Nov. 15, 1946.
48. *Drug Chem. Mkts.* 16, 205 (1925).
49. *Ibid.* 18, 793 (1926).
50. *Ibid.* 12, 399 (1923).
51. *Ibid.* 16, 1269 (1925).
52. *Ibid.* 657, 17, 74, 97 (1925), 18, 693 (1926); L. A. Watts, *ibid.* 17, 1119 (1925); W. G. Ungerer, *Pharm. Era* 60, 38 (1925); Haynes, *This Chemical Age*, p. 37.
53. *Drug Chem. Mkts.* 16, 509 (1925).
54. *Drug Mkts.* 20, 376 (1927).
55. *Soap* 29 (Mar. 1926); *Drug Chem. Mkts.* 18, 561 (1926).
56. *Drug Mkts.* 20, 265 (1927).
57. *Ibid.* 25, 365 (1929).



*PART FIVE*

THE CONSUMING INDUSTRIES





*Oil, Paint & Drug Reporter*

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## Chapter 19

### FERTILIZERS

CHILEAN ECONOMY UPSET BY AIR NITROGEN; WORLD NITRATE PRODUCERS FORM CARTEL—ANGLO-CHILEAN WORKS GUGGENHEIM PROCESS—AMMONIATED SUPERPHOSPHATE, UREA, OTHER CHEMICAL INGREDIENTS ENCOURAGE CONCENTRATED FERTILIZERS—BATTLE OVER MUSCLE SHOALS—GERMAN-ALSACE POTASH SALES AGENCY IN U. S. DISSOLVED—SEARLES LAKE IN PRODUCTION AND POTASH FOUND IN PERMIAN BASIN—DEMORALIZED FERTILIZER INDUSTRY WRITES CODE OF ETHICS, MERGES ASSOCIATIONS.

**M**ATERIALS CONTAINING the three essential plant foods—nitrogen, phosphorus, and potash—underwent technical and commercial changes during the twenties that shifted every leg of this tripod of raw materials upon which the fertilizer industry stands.

Nitrogen from the air had become a commodity.\* It upset the price structure of this vital, then most costly fertilizer component; brought new techniques in the use of ammonia liquor in fertilizer manufacture; introduced new nitrogen compounds. Through the Muscle Shoals controversy it plunged fertilizers deeper than ever into politics.

Air nitrogen ripped the domestic economy of Chile wide open. A third of the people worked directly or indirectly at mining, refining, or transporting the country's great natural resources of copper and sodium nitrate. Financing nitrate operations was the backbone of the Chilean banking system. Sales to every important country created a phenomenal, exceedingly favorable trade balance. The export duty on nitrates provided the Chilean Government with sufficient funds—frequently spent on showy, politically minded “internal improvements”—to lift the burden of domestic taxes to featherweight. Chile, thanks to its natural monopoly of sodium nitrate, was the wonder and envy of its sister South American republics.

Anticipating synthetic competition when the war ended, nitrate producers, led by the English companies, revived and greatly strengthened their association. By threats and promises, they achieved virtually a 100 per cent membership, and although 250,000 tons of Army-owned sodium nitrate were sold to American farmers<sup>1</sup> and the purchasing power of European farmers was wretchedly low, they held the market

\* See Chap. 6.



so firmly that the price actually advanced until the world-wide recession of 1921. Thereafter their difficulties multiplied like a brood of fruit flies.

Until the late twenties the American market, at once the hope and consolation of Chilean nitrate, held up well, for fertilizer consumption was greater than prewar, quite sufficient to maintain imports which between 1923 and 1929 varied only from 748,782 tons in 1927 to 1,112,226 in 1925.\* Prices were not so stable, ranging generally downward from \$2.90 per hundredweight in 1922 to \$2.07 in 1929. In Europe, however, stronger synthetic competition curtailed sales and lowered prices, skimming the cream off Chilean sales, so that many *oficinas* were starved out, creating unemployment among the workers and a business-hungry attitude among the managements.

Conflicts of interest between the large and the small, the efficient and the inefficient *oficinas*, together with the international rivalries of companies owned in England, Germany, Yugoslavia, Peru, and in Chile itself, made it exceedingly difficult to hold the Nitrate Producers' Association together. Never during the period was any agreement signed for longer than a year. The threat of dissolution and chaotic competition set all on edge.

Official action, which was frequently pretty drastic, did nothing to reconcile the conflicting interests and little to help the basic situation. The Government was subjected to political pressure on all sides, and its attitude towards the nitrate industry shifted back and forth like a shadow boxer. At first it stoutly supported the Producers' Association, bringing pressure upon reluctant or rebellious members. As sales fell off, export revenues diminished and unemployment increased, and a popular clamor arose that the producers were selfishly holding up prices for the benefit of shareholders to the ruination of the whole country. Accordingly, while steadfastly refusing to lower the export tax, the Government, charging the producers with obsolete and monopolistic methods, ordered them to disband their uniform selling system.<sup>2</sup> Thus coerced, the Chilean producers returned to free selling, July 1, 1927, and their allied group, the Chile Iodine Producers' Association, followed suit.<sup>3</sup> Having been restrained, competitive selling broke forth wildly, and the market deteriorated so rapidly that before the year was out the Association voted to resume centralized selling and fixed prices on July 1, 1928.<sup>4</sup>

While cartelized distribution did help stabilize the market, the selling system had the grave fault of turning over actual sales to brokers, importers, and agents all over the world. Accordingly producers had no direct contact with users of nitrate; dealers, no particular stake in

\* See Appendix III for annual imports; Appendix II for low-high prices.

nitrates. In fact, they frequently pushed sulfate of ammonia, natural ammoniates, and even aggressively helped to introduce the new high-nitrogen-bearing chemical competitors of Chile saltpeter.<sup>5</sup>

Repeatedly the nitrate producers suggested that a lower export tax was the most practical help the Government could give the industry. But loss of this revenue would have meant either a drastic paring down of government expenditures or the imposition of new taxes upon the Chilean people. The choice of either dilemma would have turned out the party in power. As the producers' suggestions hardened into persistent demands for tax relief, the Government introduced legislation to nationalize the nitrate fields.<sup>6</sup> The bill was a political move to warn the producers and to mollify the unemployed nitrate workers, so it was shelved. But pressure from both sides continued, and again the Government sidestepped the direct issue. In the fall of 1927 it ordered a bounty paid to all vessels carrying Chilean nitrate, hoping that lower ocean freights would improve the competitive position and so increase sales without touching the export tax.<sup>7</sup>

The following spring the formation of an international cartel by synthetic and by-product nitrogen producers forced the hand of the Chilean Government. Since 1921 British, German, and Chilean representatives had met each year at Biarritz to consider the problems arising out of the competition between ammonium sulfate and Chile saltpeter. Their fifth conference was extended to include synthetic ammonia, and in addition to the original three nations, representatives were present from France, Italy, Belgium, Holland, Java, Norway, Sweden, and the United States.\* The conference reached a price agreement.<sup>8</sup>

Next year the I.G., which was introducing the high-nitrogen chemical fertilizers, Leunasalpeter and Nitrophoska, and was keenly interested in the entire nitrogen situation, invited this conference to be its guests<sup>9</sup> and the 1928 meeting was held April 30 to May 8, aboard the S. S. *Lützow*, sailing from Venice and cruising in the Adriatic Sea.<sup>10</sup> Fifteen countries were represented, the American delegation being Irénée du Pont and J. B. D. Edge of du Pont; Walter S. Landis and Kenneth Cooper of American Cyanamid; W. N. McIlravy of Barrett; Sidney B. Haskell and Carl B. Peters of Synthetic Nitrogen Products Corporation; Charles J. Ramsburg of Koppers; W. C. Morris of the American Gas Association; and Dr. Harry A. Curtis of Yale and Firman E. Bear of Ohio State, representing the Department of Agriculture. Dr. Julius Bueb,† head of I.G.'s Stickstoff Syndikat, summed up the world nitro-

\* U. S. representatives, in the role of informal observers, were Drs. F. G. Cottrell and Russell A. Oakley. [See *Drug Chem. Mkts.* 18, 1281 (1926).]

† Dr. Bueb's review has become a classic, but there is an extensive literature covering all phases of the natural nitrate-synthetic ammonia situation during the 1920's. See particularly *Nitrogen Survey* published by Bur. For. Dom. Com.: Pt. I, on the costs of

gen situation<sup>11</sup> in a masterful address. He emphasized that while world prices of nitrogen had been declining since 1923, the prices of farm products had been advancing. The agricultural consumption of nitrogen had increased greatly, reaching a world total for the fertilizer year of 1926-27 of 1,339,000 metric tons, equivalent to 6,500,000 tons of ammonium sulfate or some 9,000,000 tons of sodium nitrate. He estimated world total production of nitrogen that year to have been 1,600,000 tons, less than half of which was provided by Chile nitrate and by-product ammonium sulfate. He concluded by crediting the synthetic nitrogen industry with not only having achieved half of the world's total output, but of having introduced concentrated fertilizer materials.

Representatives of the Chilean Nitrate Producers' Association were conspicuously absent from the *Lützow* conference, and the American representatives, although participating in the discussion, scrupulously avoided taking part in the formation of the International Nitrogen Cartel which was organized. Bueb's statistics, which no one questioned, revealed an excess production of synthetic ammonia, so lower prices were agreed upon to increase consumption.

News of a strong, virtually all-embracing international cartel with the announcement of lower prices shoved the Chilean Government into action. May 24, 1928, it agreed to pay till June 30, 1929, a bonus on Chilean nitrate equal to any price reductions made by the cartel.<sup>12</sup>

This was tangible help indeed, but the Chilean producers were well aware of the uncertainties of Chilean politics and they determined to help themselves. Negotiations were opened with the I.G. and Imperial Chemical Industries, and in June 1929 Pablo Ramirez signed for the Chileans an international agreement to balance natural and synthetic production and link the marketing of their products.<sup>13</sup> A reduction of 6 per cent from the existing price schedule was announced and the relationship between Chile and synthetic nitrate affirmed at the old ratio. In deference to our anti-trust laws the agreement did not apply within the United States, American producers of Chile nitrates being bound by its terms only when selling outside of this country. In fact, the Producers' Association's activities here were reduced to an Educational Bureau headed by William S. Meyers, who retired in 1927 and was succeeded by Wilbert W. Weir,\* formerly associate soil technologist of the Bureau of Chemistry.<sup>14</sup>

Chilean nitrate, by H. F. Bain and H. S. Mulliken (*Trade Inform. Bull. No. 170*, 1924); Pt. II, general review of the nitrogen situation in the U. S., by H. A. Curtis (*Bull. No. 226*, 1924); Pt. III, covering the various synthetic processes, by J. M. Braham (*Bull. No. 240*, 1924). See also R. S. McBride, *Chem. Met. Eng.* 35, 52 (1928); H. R. Bates, *Ind. Eng. Chem.* 20, 1133 (1928); and *Chem. Age (N. Y.)* 29, 57 (1921), 30, 197 (1922), 31, 539 (1923).

\* In 1934 Weir returned to Govt. service at the Southwest. Forest & Range Exp. Sta.,

Meanwhile the most obvious, most practical means of self-help for natural nitrates had not been neglected, and thanks largely to the Guggenheim process the cost of mining and refining *caliche* was importantly reduced. The old Shanks process, which recovered only from 55 to 75 per cent of the nitrate from hand-picked *caliche*,<sup>15</sup> held the promise of better yields and real economies through mechanical handling. So reasoned the Guggenheim brothers from their local experience in mining Chilean copper. In 1922 they began acquiring nitrate lands from the Chilean Government and started to develop mechanized mining operations and a new extraction process. Having purchased the Anglo-Chilean Nitrate & Railways Company, Ltd., they incorporated in Delaware the Anglo-Chilean Consolidated Nitrate Corporation,\* to hold and administer these properties.<sup>16</sup> At a cost of \$40,000,000 construction of a plant to operate the Guggenheim process at their Coya Norte Mine started immediately. Its output was said to be 10 per cent of the entire Chilean industry.<sup>17</sup> Despite five years of previous engineering research, it was November 1926 before this plant was in commercial operation.

From the first the Guggenheim process† was notably successful. It recovered more than 90 per cent of the available nitrate and delivered material over 98 per cent pure. The fertilizer industry noted with approval that this nitrate was whiter and drier.<sup>18</sup> It was estimated<sup>19</sup> that the new process reduced production costs by half, and its commercial success was attested by the fact<sup>20</sup> that although the very month the Guggenheim plant opened four other refining plants closed,‡ its own output was increased the next year from 125,000 to 500,000 tons.<sup>21</sup>

This engineering triumph kindled in Chile a curious mixture of hopes and fears. It was acclaimed the savior of the industry, but some foreign-owned operating companies, notably English firms, jealous and apprehensive of their position, instigated charges that the Anglo-Chilean titles to mining lands had been illegally acquired. A special government investigator completely exonerated the American interests.<sup>22</sup> Reports of the big cost-savings fed the agitation which blamed the technical backwardness and financial selfishness of the mining companies for the plight of the entire country. This line of thinking stiffened the determination of the Government not to reduce the export tax and it multiplied the difficulties of the other *oficinas*. All these hopes and fears were substantiated when in 1929 the Government called for bids for operating rights to a new, large nitrate tract known as the Nebraska field.

Tuscon, Ariz. Born in Vernon, Wis., 1882, he received his B.S., U. Wis., 1908, M.S., 1917; M.S., Cornell, 1916; Ph.D., American U., 1923.

\* Name changed, 1931, to Anglo-Chilean Nitrate Co.

† For description, see Curtis, *Fixed Nitrogen*, Chap. 3, also *Rogers' Industrial Chemistry*, 6th ed., I, 386.

‡ Leaving but 36 in operation, or 13% of those operating in 1914.

Anglo-Chilean not only put in the highest bid, £2,500,000, but it raised the Government's required production of 80,000,000 quintals of nitrate within the next twenty years to 100,000,000 quintals.<sup>23</sup> That year the Guggenheims completed their new Maria Elena plant with a yearly capacity of 500,000 tons, and effected an alliance\* with the Lautaro Nitrate Company, Ltd., of London.<sup>24</sup>

Another modern method of saltpeter extraction, developed originally in the German potash industry and known as the Banthien process, was recommended in 1928 by the Research Bureau of the Nitrate Producers' Association as adaptable to Chilean practice.<sup>25</sup> Patent rights for Chile were purchased by German interests and a company was formed, with an installation at San Pedro.

In 1929 the Chilean Nitrate Producers' Association was strengthened when the previously aloof Anglo-Chilean company became a member. This brought all nitrate sales, except in the United States, under the rule of the Association.<sup>26</sup> At this time too, the Grace Nitrate Company of New York transferred all its property in Chile to its British affiliate, the Tarapaca & Tocopilla Nitrate Company.<sup>27</sup> The combined property embraced 19,154,490 square meters in the Province of Tarapaca, and both firms continued under the operating management of W. R. Grace & Company, New York. Also in 1929 the Chile Republic underwrote as an educational subsidy a grand prize of \$5,000 known as the Chilean Nitrate of Soda Nitrogen Research Award. It was divided in 1929 by the American Society of Agronomy, which served as judge, between P. L. Gainey, professor of soil bacteriology at the Kansas Agricultural College; C. A. Mooers, director of the Tennessee Experiment Station; and S. A. Waksman, associate professor of soil microbiology at the New Jersey College of Agriculture.<sup>28</sup>

Technical efforts to increase the values in the *caliche* were also made at this time. One *oficina* began producing refined sodium nitrate sufficiently pure to pass the rigid U. S. Government requirements for use in meat packing.<sup>29</sup> This high-grade salt had been produced for many years in this country by recrystallizing ordinary Chilean saltpeter. Several plants working *caliche* notably high in potassium nitrate, began making mixed sodium-potassium nitrate, an idea that had been proposed and three processes worked out as early as 1920.<sup>30</sup>

While the Chilean nitrate industry was having its struggles, technical developments in nitrogen that more directly affected the American fertilizer industry were coming to a head. Germany was leading the

\* In exchange for an agreement to build a new 540,000-ton Guggenheim plant and license to operate the process, Anglo-Chilean received over 50% of the 4,000,000 no-par common shares of Lautaro Nitrate Corp., a Del. corp. owning 2,000,000 ordinary shares of Lautaro Nitrate Co., Ltd. Cost of the plant was met by the sale of \$32,000,000, 25-yr., 6% convertible bonds of Lautaro Corp. (See *Poor's Manual of Industrials*, 1930, p. 2699.)

commercial exploitation of new chemical plant-food compounds. In the early 1920's the I.G. marketed Leunasalpeter (ammonium sulfate-nitrate) and Floranid,\* which were brought to this country by Kuttroff, Pickhardt & Company in 1925<sup>31</sup> and sold by C. B. Peters Company.† In 1927 Nitrophoska (ammonium phosphate-potash), the output of which had reached 10,000 tons monthly, also appeared here through the same channels.<sup>32</sup> It was rumored that I.G. proposed to build a synthetic ammonia plant and produce high-nitrogen plant-food ingredients in the United States,<sup>33</sup> and Dr. Bueb in an interview in *Chemical Markets*<sup>34</sup> skillfully confirmed this impression. In the spring of 1927, however, the Synthetic Nitrogen Products Corporation, incorporated in Delaware with a capital of \$500,000,<sup>35</sup> secured American sales representation of the Stickstoff Syndikat, I.G.'s fertilizer subsidiary. At this time Carl Peters joined the organization as vice-president in charge of sales, and Sidney B. Haskell, ‡ director of the Massachusetts Experiment Station, became head of the new corporation's educational work, becoming general manager in 1929 and president in 1931.<sup>36</sup>

The high hopes of the Germans for big American sales of these concentrated chemical plant foods were never realized, for high-test fertilizer ingredients developed in this country along independent lines. Most important of these innovations was the treatment of superphosphate with liquid or anhydrous ammonia. § That bold and original inventor of American mixed fertilizers, James J. Mapes, had originated this idea, using gas-house ammonia liquor, in the 1850's.<sup>37</sup> A similar process was

\* "Floranid was the copyright trade name under which urea was offered in small packages to the garden trade and as such was without industrial significance. Urea-calcium nitrate was brought in somewhat later and offered under the trade name Cal-urea. . . . Up to the passage of the Hawley-Smoot Tariff, urea was subject to an almost prohibitive tariff (35% ad valorem) while Calurea came in duty-free. Naturally and inevitably urea replaced Calurea completely when the Hawley-Smoot Act allowed its importation duty-free." (S. B. Haskell, to author, Nov. 23, 1946.)

† A lifelong importer of chemicals, Carl B. Peters, who was born in Switzerland, was from 1902-19 with Charles F. Garrigues Co., which in 1927 became Garrigues, Stewart & Davies. In 1919 Peters, who was Maj. in charge of explosives procurement, Ordn. Dept., U.S.A., during the war, established C. B. Peters Co. and in 1927 joined Synthetic Nitrogen Products Corp. After World War II he again established his own business as importer of chemicals.

‡ Well-known agronomist, Haskell, born in Fargo, N. D., in 1881, got his B.S. at Mass. Coll. Agr. in 1904, studied at Leipzig, and returned to Mass. as prof. agron., 1909-16. Between 1916 and 1920 he was head of the soil improvement educational work for the Nat. Fertil. Assoc. and till 1927 dir., Mass. Exp. Sta. In 1937 he left Synthetic Nitrogen Products to become vice-pres. of the Barrett Co. In 1940, when the Barrett organization was absorbed by Allied, he became mgr. of sales agencies with no change in responsibilities.

§ For a firsthand account of these developments, see memo to author from C. H. MacDowell, Appendix XLI, and for review of pats. and techniques, F. G. Keenen, *Ind. Eng. Chem.* 22, 1378 (1930).

patented in 1873 by John McDougall,\* but there was no successful application until after 1925, when the price of ammonia was halved, thus making it available at a cost feasible for fertilizer use.<sup>38</sup> Among American fertilizer manufacturers, the leader in ammoniated superphosphate was the Armour Fertilizer Works, but du Pont and Allied entered enthusiastically into researches to perfect the technique to provide an ammonia outlet for their Belle and Hopewell plants.<sup>39</sup> By 1930 the new method had been tried out in approximately 100 different fertilizer plants,<sup>40</sup> and was generally adopted by the larger manufacturers.

Urea was also being explored as a possible fertilizer chemical. Union Carbide and Carbon purchased manufacturing rights to a process discovered by Johan H. Lidholm of the Swedish Wargons Company, in which an aqueous solution of cyanamide is treated with carbon dioxide. Upon the basis of this process Union Carbide bid unsuccessfully for U. S. Nitrate Plant No. 2, at Muscle Shoals,<sup>41</sup> but domestic urea did not become a fertilizer ingredient till the 1930's.

An entirely new source of fertilizer nitrogen appeared in 1927 when sewage and trade wastes treated at Milwaukee's Activated Sludge Disposal Plant were converted into a plant food and offered under the trade name of Milorganite.<sup>42</sup> Its fertilizer value, based on nitrogen and phosphorus content, was established by experimental work at the University of Wisconsin, and the output in 1928 was estimated at between 30,000 and 35,000 tons. It also became apparent that the most popular current source of organic nitrogen, cottonseed meal, was moving rapidly into cattle feed, where its value was six times as great as in fertilizers.<sup>43</sup>

Piquant chemical ideas also stirred the makers of superphosphate,† poundwise the most important fertilizer (world output then 15,000,000 tons, a quarter of which was consumed in this country). Improvements in this prosaic process of treating phosphate rock with sulfuric acid were developed about 1926 under the sponsorship of G. Ober & Sons Company of Baltimore, which licensed the new method under the name of the Oberphos process.‡

All these technical innovations were eclipsed by a threat to the fertilizer manufacturers that was something quite new in American industry, direct competition from their own government. During the 1920's the disposition of the Muscle Shoals power facilities and air-nitrogen plants (No. 1, a modified Haber process built by General Chemical and No. 2 a cyanamide operation built by American Cyanamid) became increasingly ensnarled in politics, and as the proposals of private interests failed to win Congressional approval, agitation for government operation, per-

\* U. S. Pat. 135,995.

† See Chap. VII.

‡ For details of method and apparatus, see M. Shoeld, *Chem. Met. Eng.* 41, 178 (1934).

sistently advocated by Senator Norris of Nebraska, won more and more adherents.

Possibly this was inevitable. Friendship with the farmer was politically profitable. Cheap electric power was played up as a benefit to city dwellers. Nitrogen independence fitted in perfectly with the isolationistic ideas then held by the country, and the patriotic appeal to national defense made government operation seem plausible and obscured the underlying economic issues. These mixed motives, inspired by political expediency and encouraged by emotional thinking, built up Congressional support for government operation of Muscle Shoals. This might not have happened if the private interests who made bids had been less shortsightedly selfish and had cooperated in a sharper definition of the fundamental issues involved.

The voluminous verbatim records of the hearings<sup>44</sup> held during these years on the numerous bills for the disposal of Muscle Shoals are enlightening. They explain why Congress, despairing of reconciling these conflicting interests with all their contradictory claims, turned in desperation to government operation. Bids from companies varied so widely that comparison was almost impossible. The 68th Congress, for example, had before it four proposals,\* the direct financial return to the United States from Union Carbide and Carbon being \$36,754,200, from Hooker Electrochemical, \$113,274,738, from Henry Ford, \$115,906,896, and from the Alabama Power and associated power companies, \$134,909,320.<sup>45</sup> Union Carbide was interested only in Nitrate Plant No. 2, Dam No. 3, and the Waco Quarry, and proposed to generate power only for its own requirements. The power companies (Alabama Power, Tennessee Electric Power, and Memphis Power & Light) on the other hand, wanted the entire installation, including the steam plant, and they proposed not only to generate and sell power, but to manufacture nitrate fertilizers. The Union Carbide bid was predicated upon the manufacture of cyanamide to be converted into urea under the Lidholm patents† and the eventual manufacture of "Phosphazote," a fertilizer mixture containing urea and phosphates.<sup>46</sup> Hooker planned to install a Casale process plant and make cheap fertilizer from the ammonia by combining this with phosphoric acid produced in the electric furnace.<sup>47</sup> Ford, who withdrew his bid after it passed the House and was defeated by the Senate, was said to be planning extensive electro-metallurgical operations to provide steel and possibly aluminum for his own needs.

These confusing proposals were buttressed with contradictory expert opinion as to the value and industrial potentialities of the Muscle Shoals

\* For a summary, see *Ind. Eng. Chem.* 16, 650 (1924); J. W. Hammond, *Am. Ind.* 19 (Aug. 1924).

† U. S. Pats. 1,380,223 (1921); 1,436,179-80 (1922); 1,444,255-6 (1923).



properties. The modified Haber plant was obviously not a practical installation: the cyanamide process was accused of being technically obsolete. Admittedly, the water supply was insufficient for continuous power generation, but even the power requirements of the nitrate plants were uncertain.<sup>48</sup> The testifying experts muddled more than they clarified the technical complexities which confused the lawmakers. Too often witnesses were at greater pains to pick flaws in competing proposals than to make their own case clear and strong. To cap the climax, C. J. Graff, president of the American Nitrogen Products Company, came from Seattle to testify that all bills for leasing or selling Muscle Shoals or for its operation by the Government should be voted down unless Congress was also willing to vote a substantial subsidy to every existing air-nitrogen plant in the country.<sup>49</sup>

Five years of competitive bidding, futile debate, and political jockeying had accomplished nothing. Hastily, in the closing hours of the 68th Congress, the House passed a resolution calling upon President Coolidge to create a Muscle Shoals Commission,<sup>50</sup> composed of a representative citizen familiar with the enterprise, a farmer, and a chemical engineer, to do a little intelligent fact-finding and render an unbiased opinion. The President selected with great care, naming John C. McKenzie, former Representative from an agricultural district in Illinois, chairman; Nathaniel B. Dial, former South Carolina Senator and an industrialist intimately connected with the Virginia-Carolina and the Reedy Power Companies and various cotton, cottonseed oil, and glass enterprises; Harry A. Curtis,\* Yale professor of chemical engineering; Russell F. Bower, representative of the Farm Bureau Federation; and William McClellan, a consulting electrical engineer, formerly associated with Westinghouse, Church & Kerr. Conscientiously they read stacks of technical reports and published testimony, and behind closed doors questioned qualified witnesses. Among these was Charles H. MacDowell who wrote a report † which the National Fertilizer Association distributed widely as representing its views on the Muscle Shoals project. November 14 the Commission's long-awaited report went to the White House—in fact, two reports, for McKenzie, Dial, and Bower recommended leasing Muscle Shoals for private operation for no longer than fifty years, adding that if a satisfactory lease could not be negotiated

\* Curtis was well qualified since he was an able engr. and had just completed the nitrogen survey for the Com. Dept. Later he was converted to government operation and became chem. engr. of the Tenn. Valley Authority, 1933-38, when he returned to educational work as dean, Coll. Eng., U. Missouri. He was born in Colo., 1884, and trained at U. Colo., A.B., 1908; A.M., 1910; U. Wis., Ph.D., 1914. He taught at Colo., Northwestern, and Yale, was chem. for various coal companies, and from 1931-33 headed research and development at Vacuum Oil.

† *The Problems of Muscle Shoals*, privately printed, Chicago, 1925, 36 pp.

the Government should operate the property. Curtis and McClellan opposed government operation under any circumstances and recommended that a Muscle Shoals Board should arrange the best possible lease.<sup>51</sup> Coolidge rejected the lease idea \* and in his message to Congress three weeks later, urged immediate, outright sale to the highest bidder.<sup>52</sup>

Urged thus to action, Congress appointed a Joint Committee which received bids<sup>53</sup> for the entire Muscle Shoals property from Union Carbide, Elon H. Hooker and associates, the American Nitrates Company (guaranteed by American Cyanamid), and from the Muscle Shoals Fertilizer Company on behalf of 13 power-producing and distributing corporations, while the American Nitrogen Products Company of Seattle bid for Plant No. 1.† The proposal of the power group won approval from the Committee, but failed to pass the Senate.<sup>54</sup> At this session Senator Norris introduced his first government-ownership bill. ‡

The Muscle Shoals controversy was next doubly enlivened by a new bidder, a group of farmers proposing<sup>55</sup> a cooperative, the Farmers' Federated Fertilizer Corporation, § and by the proposal of Representative Bell that \$150,000,000 be appropriated to manufacture ammonium phosphate for sale to farmers at cost.<sup>56</sup> The contest soon centered, however, on three proposals: government ownership and the bids of the associated power companies and American Cyanamid. Each was vigorously advocated by Senators Norris, Deneen, and Heflin, respectively, and since these sponsors could not agree on any compromise, again the end was a deadlock.<sup>57</sup>

During 1928 the contest narrowed to two proposals—the Willis-Madden bill, embodying the oft-revised bid of American Cyanamid, and the Norris bill, authorizing government operation. Although the former was endorsed by the Farm Bureau<sup>58</sup> and the President was well known to be unalterably opposed to putting the Government in the retail power and fertilizer business, nevertheless the Norris bill passed. It was killed by a pocket veto. The President objected both to government operation

\* The President mistrusted government operation, for he said, "If anything were needed to demonstrate the almost utter incapacity of the National Government to deal directly with an industrial and commercial problem, it has been provided by our experience with this property." He did not comment publicly upon the Commission's report, but it was subjected to severe technical and economic criticisms. [See *Ind. Eng. Chem.* 18, 197 (1926).]

† Other total bidders were H. D. Walbridge, N. Y. City; Lloyd H. Smith, Battle Creek, Mich.; and F. E. Castlebury, Shreveport, La.; while Jas. H. Levering, Wash., D. C., bid for Plant No. 1.

‡ S. 2147 (69:1), providing for "the operation of Dam #2 at Muscle Shoals, Ala., for the construction of other dams on the Tennessee River and its tributaries, for the incorporation of the Federal Power Corp. and for other purposes."

§ Supporters of this proposal were John W. Newman, Versailles, Ky.; A. P. Sandles, Ottawa, O.; A. L. Sponsler, Hutchinson, Kan.; and C. Blascom Slemple, former secy. of Pres. Coolidge.

and the expenditure of additional money to install generators at Wilson Dam.<sup>59</sup> Both these proposals were before the next Congress, but Senator Norris' bill, approved by the House Military Affairs Committee 17 to 4, was revised until one of its main purposes was plainly to place the Government in the fertilizer business as a manufacturing corporation.<sup>60</sup> Thoroughly aroused, the National Fertilizer Association, through its secretary, Charles J. Brand,\* vigorously protested this legislation.† Both bills were re-introduced in 1929, but Congress adjourned in a stalemate.<sup>61</sup>

Attempting to shift the blame for ten-years' Congressional shilly-shallying, Senator Hugo L. Black of Alabama, in two speeches, October 4 and 9, savagely attacked the chemical industry for declining to provide nitrogen-fixation plants for the country's munition and fertilizer needs and demanded an investigation of the fertilizer lobby. Brand answered for the Fertilizer Association, welcoming an investigation and pointing out that 26,000 tons of synthetic nitrogen had been produced in 1928, and 80,000 were expected in 1929, or twice the Muscle Shoals capacity.<sup>62</sup> By 1930, he concluded, private plants operating at Hopewell, Belle, Niagara Falls, Syracuse, Seattle, and Pittsburg, California, would produce 80 per cent of the country's total nitrogen requirements.

No such stimulating chemical innovations or upsetting political agitation occurred in potash during the 1920's, but the first commercial trial of the deposits in New Mexico and West Texas established a domestic source of this essential plant-food element, a commercial event of wide significance. The swift, if not painless, death of our war-born potash industry, ‡ restored the domination of German-Alsatian potash. The

\* Born on a Minn. farm, 1879, Brand was trained at U. Minn. and joined Dept. Agr. in 1903. In 1913 he became chief of U. S. Bur. Markets and as such conducted food and fertilizer surveys during World War I and was in charge of distributing government-bought nitrates to farmers. He was also chmn. of the War Ind. Bd. Comm. on Cotton Distribution. In 1933 he served with Geo. N. Peek as joint administrator of the Agr. Adjust. Act. He was exec. secy. and treas., Nat. Fertil. Assoc., from 1925 till 1945, when he retired and engaged in consulting practice.

† Some of the fertilizer manufacturers who appeared against the bill were: E. L. Robins, pres. Nat. Fertil. Assoc. and Meridian Fertilizer Factory; H. Bowker, American Agricultural Chemical Co.; J. H. Anderson, Anderson Fertilizer Works; C. H. MacDowell, J. E. Sanford, Armour Fertilizer Works; B. H. Brewster, Jr., Baugh & Sons Co.; W. D. Huntington, Davison Chemical Co.; J. J. Watson, J. T. Burrows, International Agricultural Corp.; E. H. Meadows, Meadows Fertilizer Co.; E. H. Pringle, Merchants' Fertilizer & Phosphate Co.; Geo. Ellis, Mutual Fertilizer Co.; C. L. Ives, New Bern Cotton Oil & Fertilizer Co.; G. Ober, Jr., G. Ober & Sons Co.; W. B. Metts, Planters' Fertilizer & Phosphate Co.; S. J. Martenet, E. Rauh & Sons Fertilizer Co.; C. F. Burroughs, F. S. Royster Guano Co.; A. D. Strobhar, Southern Fertilizer & Chemical Co.; J. S. Coale, I. P. Thomas & Son Co.; C. G. Wilson, S. L. Carter, A. L. Ivey, Virginia-Carolina Chemical Co.; L. A. Wilson, Wilson & Toomer Fertilizer Co. [See *Chem. Mkts.* 22, 568 (1928).]

‡ See Vol. II, Chap. 15.

obsequies were held in 1923, when the Eastern Potash Corporation,<sup>63</sup> Waldemar Schmidtman's ambitious project to exploit the greensands of New Jersey, went into a receivership and the last of the potash plants in the Nebraska fields\* closed down. There were left but three survivors: the U. S. Industrial Alcohol Company,<sup>64</sup> recovering potash from the burnt residue of fermented molasses; † the potash-borax plant of the American Trona Company, struggling with technical difficulties in refining Searles Lake brine; and a small, scattered by-product output from cement plants.<sup>65</sup>

The Kali Syndikat and the Société Commerciale des Potasses d'Alsace, having agreed on a 66-33 division of international markets, set up a selling company, the N. V. Potash Export My. ‡ in Holland, to handle sales abroad.<sup>66</sup> In 1927, as a follow-through of the Commerce Department's investigation of foreign monopolies, the Department of Justice indicted 16 defendants, including the German and French syndicates, the Potash Importing Corporation of America, § and individual officers of these organizations. This suit raised the question whether the U. S. court had jurisdiction over the French potash combine in which eleven of the mines and a majority of the stock were, according to the terms of the Versailles Treaty, vested in the French Government.<sup>67</sup> Gilbert H. Montague, attorney for the French defendants, Jean Le Cornec, Pierre Gide, René Gide, and Walter B. Howe, made this argument before Judge William Bondy, who ordered a recess of 30 days to give the French Ambassador time to decide whether or not he would plead sovereign immunity. Ambassador Claudel did so, maintaining that the French defendants had not violated the anti-trust law and that the suit was in effect against the French Republic. Judge Bondy ruled that the defendant company was not exempt under the laws of the United States,<sup>68</sup> and the case was finally closed by a consent decree, February 28, 1929, binding the defendants and their agents to observe the anti-trust laws, the court retaining jurisdiction to enforce the decree.<sup>69</sup>

In 1924 the American Trona Company, after thirteen years of ups and downs, began producing potassium chloride, with 60 per cent  $K_2O$ , at a competitive cost with imported materials.<sup>70</sup> In 1926 the old corpo-

\* This plant, said to have cost \$1,000,000, was sold for junk for \$6,500 in 1929. (See *O.P.D. Repr.* 72, Sept. 30, 1929.)

† This by-product production persisted and in 1928 the potash output of the Curtis Bay plant was reported to be more than 12,000 tons, sold through H. J. Baker & Bro. [See *Chem. Mkts.* 23, 51 (1928).]

‡ An office was opened in N. Y. with Robert Kunze and René Gide as directors. Sales were managed by C. C. Smith and W. B. Howe.

§ Inc. in Del., 1923, with \$250,000 capital to handle German potash in this country, selling being through H. J. Baker & Bro. Its officers were E. K. Howe, pres.; H. A. Forbes, treas.; A. G. Vogel, gen. mgr. [See *Chem. Met. Eng.* 28, 181 (1923); *Drug Chem. Mkts.* 12, 78, 141, 211, 1171 (1923).]

ration was replaced by the American Potash & Chemical Corporation,\* chartered in Delaware with a capitalization of \$1,000,000.<sup>71</sup> In 1929 it was announced<sup>72</sup> that the British corporation, Consolidated Gold Fields of South Africa, Ltd., which with dogged faith had financially backed the long drawn-out experimental work at Searles Lake, had sold 90 per cent of its stockholdings to Dutch interests.†

Meanwhile, production at Trona had been doubled at a cost of \$2,200,000.<sup>73</sup> At the time it accounted for 85 per cent of our domestic potash while 10 per cent came from U. S. Industrial Chemical, the remainder being by-product material chiefly from cement mills.<sup>74</sup> The full significance of this triumph of patient skill was not overlooked. In 1927 the Perkin medal was awarded to John E. Teeple<sup>75</sup> for his contribution in solving the technical problems and the broad economic meaning was pointed out by George W. Stocking.‡ While Searles Lake, he wrote,<sup>76</sup> showed no immediate prospect of freeing this country from foreign dependence, it was an heartening exception to the fatalities inflicted by German competition.

So encouraging was this Trona success that it inspired a number of similar brine-potash projects. In California in 1923, the Soda & Potash Corporation was formed to build a \$1,500,000 plant to produce industrial and pharmaceutical sodas and agricultural potash from its deposits in Nevada. The officers were C. W. Culpepper, president; Charles W. Berry, vice-president; E. P. Shaw, treasurer; and F. J. McGuire, secretary.<sup>77</sup> Three years later a pioneer of soda exploration in the Far West, Clinton E. Dolbear, with Henry M. Leland, president of the Cadillac automobile company, secured a government lease on 2,000 acres at Searles Lake upon a royalty basis and with an obligation to spend \$500,000 within the next four years.<sup>78</sup> In 1929 the old Trona Company plant buildings at San Pedro, California, and a phosphate mine in southeastern

\* Officers were Count L. A. G. Dru, pres.; H. S. Emlaw and F. C. Baker, vice-pres.; Frederic Vieweg, mgr. at Trona; John E. Teeple, consulting chem. engr.

† During World War II, the Alien Property Custodian revealed a substantial German-owned interest in the 90.79% of the foreign-owned stock of American Potash & Chemical: 75,760 shares by Administratiekantoor Diligentia for Wintershall A.-G. and Salzdetfurth A.-G. F. Cecil Brown, pres. of the co., made this statement after the disclosure of foreign ownership: "The stock in question was sold by Consolidated Gold Fields of South Africa, Ltd., a British company, which had been responsible for the financing and development of the Trona enterprise since . . . 1913, to Hope & Co. of Amsterdam, one of the most respected banking houses in the Netherlands. This sale took place in 1929. Since the sale of this stock, the officials of American Potash have been assured many times by Hope & Co. that none of it was being held for the benefit of German interests." American Potash officials cooperated actively with the Govt. in this investigation and the Alien Property Custodian absolved the American executives of any blame. (See *O.P.D. Repr.* 3, Nov. 2, 1942; 4, Nov. 9, 1942.)

‡ Author of that admirable monograph, *Potash: A Study in State Control*, well-known arbiter in labor disputes and student of cartels and monopolies, Stocking has been prof. econ. at U. Texas since 1926, and since 1947 at Vanderbilt.

Idaho were taken over by the Agricultural Potassium-Phosphate Company of California, Ltd.<sup>79</sup> Manufacture of ferrophosphorus, trisodium phosphate, and a new inorganic fertilizer material, by a process patented by A. L. Kreiss,\* the president, was projected at a rate of 40,000 tons a year.

If these brine projects disappointed the optimistic expectations of their sponsors, the hope of potash independence was realized in the deposits of the Permian Basin in West Texas and New Mexico. The first discovery † had been made by Johan A. Udden‡ in 1912, and by 1923 signs of subterranean potash beds in oil-well drillings had been reported from 13 different locations in West Texas.<sup>80</sup> In 1924, Max Agress of Dallas, Texas, organized a potash exploration company which in May 1926 obtained a five-foot core of pure polyhalite at a depth of 2,100 feet in the southwestern corner of Midland County, Texas. Incorporated in 1928 as the American Potash Company, in Dallas, this group later that year became the Standard Potash Corporation, with Homer R. Mitchell as president, Tom Leackman as secretary, and J. B. Adams as treasurer. They drilled another well five miles west of the first and found there the same five-foot layer of polyhalite at approximately the same depth, which indicated this deposit was very extensive.<sup>81</sup> In 1925 Senator Sheppard introduced a bill (S. 1925) appropriating \$500,000 for prospecting potash in the Southwest. Hearings§ were held<sup>82</sup> and for two successive years this bill passed the Senate but failed in the House,<sup>83</sup> so that it was 1926 before funds were available. The Geological Survey began systematic core-drilling and testing, which indicated potash in 28 additional wells in eight counties in Texas and three in New Mexico,<sup>84</sup> bringing the total of such discoveries in early 1927 to about 70 wells.

The principal potash salt of the Permian deposits, as indicated by this survey, is polyhalite, a complex sulfate of potash, lime, and magnesia ( $2\text{CaSO}_4 \cdot \text{MgSO}_4 \cdot \text{K}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$ ) with an average  $\text{K}_2\text{O}$  content of 12-15 per cent. Associated with it is a similar chloride, carnallite ( $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ).<sup>85</sup> At the Bureau of Mines Nonmetallic Minerals Experiment Station, New Brunswick, New Jersey, H. H. Storch¶ and Loyal W.

\* U. S. Pats. 1,366,569 (1921); 1,413,168 (1922).

† See Vol. II, p. 147; also Turrentine, *Potash*, p. 160.

‡ Udden (1859-1932) was born in Sweden and came to U. S. when 3 yrs. old. Most of his career as teacher and geologist was spent in Texas where he not only discovered the potash beds but forecast the finding of oil on U. Texas lands. He received hon. degrees from his Alma Mater, the Swedish Augustana Coll., Rock Is., Ill., Bethany Coll., and Texas Christian U., and was knighted by the King of Sweden.

§ Appearing for this bill were Geo. O. Smith, Geo. R. Mansfield, and Walter B. Lang, Geol. Surv.; and John W. Turrentine, Bur. Soils.

¶ Storch, born in N. Y. City, 1894 (C.C.N.Y., B.S., 1915; U. Calif., A.M., 1915, Ph.D., 1923), later went to the Pittsburgh Sta., Bur. Mines, and had previously been with the

Clarke worked out an extraction process.<sup>86</sup> Another method was developed by Eugene P. Schoch,\* at Texas University, where this promising new natural resource of the Lone Star State roused such interest that E. H. Sellards, director of its Bureau of Economic Geology was sent to Europe to study the French and German potash mines.<sup>87</sup>

Private interests in the meantime got wind of a much more important potash deposit. This had been discovered near Carlsbad, in southeastern New Mexico in 1925 by V. H. McNutt, consulting oil geologist, who interested the Snowden & McSweeney Company, petroleum drillers, in his discovery. Further exploration by this company revealed a 6 to 12-foot bed of high-grade sylvinite (a mixture of potassium and sodium chlorides) at a depth of less than 1,000 feet. It promptly recognized the potash deposit to be equal to the best of the European deposits, and thereupon proceeded to the organization of the United States Potash Company, originally known as the American Potash Company.† A shaft was started in 1929 and in 1930 the first American potash from the old Permian Basin reached the surface.<sup>88</sup>

This rush of new developments among all three of their raw materials struck the fertilizer makers at a difficult time. Although American synthetic ammonia had thus far been used chiefly in chemical operations, nevertheless, at the 1927 meeting of the National Fertilizer Association,<sup>89</sup> C. C. Concannon forecast higher-test formulas by employing synthetic products. Two years later, at the same convention, the economic impact of cheaper, stronger phosphoric acid was surveyed by K. D. Jacob,<sup>90</sup> who emphasized that there were already five double super-phosphate plants in operation in the United States. Agitation for higher plant-food formulas<sup>91</sup> shifted the focus of competition and increased its pressure. It was accompanied by continuous propaganda, sharpened by the Muscle Shoals debate, for lower fertilizer prices. Pressure upon prices was squeezed harder by the rise of farmers' cooperatives which sold both ingredients for home-mixing and complete formula fertilizers. Competition between the large manufacturers and the small mixers was also intensified. It was estimated<sup>92</sup> that the greater overhead cost of the large firms gave an average \$10-per-ton advantage to the local concerns whose position was further improved by a new selling policy for German potash. Prewar, it had been sold only in 50,000-ton lots, and the

Burnham Chemical Co., 1924-25, and Roessler & Hasslacher, 1925-28. Clarke, born in Billings, Mont., 1904, was trained at Ore. State U. and Calif. Inst. Tech. and has been with the Bur. Mines since 1928, now at Pittsburgh Sta.

\* A German by birth (1871), Schoch has been teaching chem. at U. Texas, his Alma Mater (C.E., 1894; A.M., 1896) since 1897, becoming prof. in 1911 and dir. ind. chem., Exp. Sta., in 1914. He holds a Ph.D. from Chicago U.

† There was still a third "American Potash Co.," inc. in Kansas, exploring for potash in the Southwest. [See *Eng. Min. J.* 127, 336 (1929).]



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large firms, acting as distributors, enjoyed a spread of \$3 a ton on this ingredient. Finally the income of American farmers sank steadily during the twenties and added to the lowering purchasing power of the industry's customers was their well-fed distrust. The protest of Charles J. Brand<sup>93</sup> that the industry as a whole earned only 4 per cent on its net in 1928 was quite futile. Farmers were convinced that fertilizer manufacturers wallowed in enormous profits.

On December 10, 1926, Judge Morris A. Soper in the Federal Court at Baltimore, fined 38 fertilizer companies sums ranging from \$1,500 to \$3,500 for unfair trade practices.<sup>94</sup> The companies\* were charged with entering into illegal agreements to lessen competition and this verdict was widely accepted as proof positive of the monopolistic wickedness of the fertilizer manufacturers. The impression of monopoly it created was quite false. With the possible exceptions of insecticides and alkalis, competition in fertilizers was keener and more cutthroat than among any other chemicals. There is no doubt that fertilizer manufacturers attempted to establish uniform discounts to local distributors, to standardize credit terms, and to equalize freight rates against certain key manufacturing points. Secret arrangements upon these conditions of sale were the means of much hidden price cutting and the cause of great market demoralization. The testimony brought out clearly that these efforts failed signally.† That two of the defendants were already in bankruptcy is presumptive evidence that the "monopoly" was neither profitable nor efficient.

The difficulties of the industry were reflected in the individual companies. While two of the "Big Six," Virginia-Carolina and International, went through reorganizations in which the banking firms involved played prominent parts, only one fertilizer company, defying the warning that multiple operation did not bring corresponding economies, vigorously expanded during the twenties. The Davison Chemical Company, heretofore engaged principally in the production of sulfuric acid and superphosphates, branched out into complete fertilizers. In 1926, increasing its capital stock from 236,000 to 400,000 shares, it bought the

\* Three of the defendants did not plead (Meridian, Mutual, and McCabe Fertilizer Companies) and two (Carolina Chemical Co. and Hand Trading Co.) were reported to the court in liquidation. The others were: Adair Bros. & McCarthy, American Agricultural Chemical, Armour, Baugh & Sons, Caraleigh Phosphate, Central Chemical, Cotton States Fertilizer, Darling & Co., Davison, Eastern Cotton Oil, Empire State Chemical, Etiwan Fertilizer, Farmers' Fertilizer, Federal Chemical, Griffith & Boyd, International, Miller Fertilizer, Ober & Sons, Planters' Fertilizer, Priddy & Co., Rauh & Sons, Read Phosphate, Reliance Fertilizer, Royster Guano, Smith Agricultural, Southern Fertilizer, Summers Fertilizer, Swift, Thomas & Son, Tunnell & Co., Virginia-Carolina, Welch Chemical, Wilson & Toomer, and Wuichet Fertilizer.

† "The poor devils deserve some credit for doing their best to be monopolistically wicked. They were like Kipling's imps who 'weep that they bin too small to sin to the height of their desire.'" (H. A. Curtis, to author, Nov. 27, 1946.)

Eastern Cotton Oil Company, and the Alliance, Camp, Meadows, and Miller Fertilizer Companies.<sup>95</sup> The following year the Lewes Fertilizer Company fish scrap plant at Lewes, Delaware, was taken over as a mixing unit for superphosphates from Davison's Curtis Bay plant and the Pick Fertilizer Service of New Orleans was purchased.<sup>96</sup> In 1928 the important Read Phosphate Company of Charleston, with four plants, the Welch Chemical Company, and the Porter Fertilizer Works were all acquired, and A. C. Read and the Earl of Denbigh of Rio Tinto joined the Davison board of directors.<sup>97</sup> This expansion was accelerated in 1929 by the purchase of the Berkshire Chemical Company, the Central Chemical Company, the Lancaster Bone Fertilizer Company (paid for by the issue of 32,682 additional shares of Davison's no-par common stock), the Fremont Cotton Oil Company, the Oxford Packing Company, and Washington, Alexander & Cook.<sup>98</sup>

While Davison was thus aggressively growing, the industry as a whole was going through sundry realignments. In 1923 the Virginia-Carolina Chemical Company sold its holdings in American Cyanamid Company to Benjamin N. Duke for a sum widely estimated at "somewhere between \$1,500,000 and \$2,000,000."<sup>99</sup> In 1925 the Standard Fertilizer Company of Reading, Pennsylvania, took over the Home Fertilizer Company of Baltimore, and the next year ownership of two important companies changed hands when A. F. Pringle purchased for \$700,000 the Richmond Guano Company plants at Richmond, Virginia, and Greenville, North Carolina, and C. B. Clay and his associates bought control of the Cotton States Fertilizer Company, Macon, Georgia.<sup>100</sup> O. F. Smith and R. B. Rowland, Jr., who had started the Smith-Rowland Company with a fertilizer plant at Norfolk, Virginia, in 1920, incorporated in 1927 with \$50,000 capital.<sup>101</sup> Somewhat out of the regular line was the Limestone Fertilizer Company, of which J. P. Magnusson was president, which was incorporated for \$1,500,000 in 1927 to convert a calcite deposit near Burlington, Iowa, into plant and animal foods,<sup>102</sup> while down in Texas the United Chemical Company of Dallas, which started in 1922 with a capitalization of \$30,000 and had grown by 1929 to a \$250,000 concern making sulfuric and nitric acid and superphosphates, was held up as one of the first shining examples of the future chemical development of that state.<sup>103</sup>

One constructive move of the period was the joining of the Southern Fertilizer Association and the old National Fertilizer Association.<sup>104</sup> This consolidation of activities was diplomatically engineered by Horace Bowker of the American Agricultural Chemical Company, chairman of the Organization Committee, and consummated at White Sulphur Springs, June 11, 1925, when Spencer L. Carter \* was elected president;

\* Virginia-born, 1872, and graduate of Va. Mil. Inst., Carter, after 4 yrs. with the

Edward L. Robins, vice-president; Charles J. Brand, executive secretary and treasurer.

A less successful effort, but exceedingly revealing as to the problems of the time, was the writing of a code of ethics. In 1927 the anti-trust proceedings had revealed the demoralized state of competition, and at the suggestion of the Department of Commerce, which was fathering these public statements of industry policy, the code was drawn up by A. C. Read, Read Phosphate Company; Horace Bowker, American Agricultural Chemical Company; Wood Crady, Federal Chemical Company; Gustavus Ober, Jr., G. Ober & Sons Company; with John Foster Dulles of Sullivan & Cromwell and also a director of the American Agricultural Chemical Company, as legal counsel.<sup>105</sup> This code \* emphasized standardized methods of cost accounting to assure fair price determination; sales in carload lots only; a reduction in the number of grades and brands; elimination of all rebates for trucking, warehousing, and special formulas; and uniform terms of credit. It came out flatly for no guarantee against price decline. Formally endorsed by such leaders as C. F. Burroughs, Warner D. Huntington, Spencer Carter, L. E. Ellwood, A. B. Grafius, and many others, it was formally approved at a meeting January 10, 1927, and adopted by 224 manufacturers, representing 85 per cent of the tonnage. Later, a total of 304 companies agreed to abide by the code provisions. Such a declaration of principles, which was shortly to become a prominent part of the National Recovery Act, served the useful purpose of setting up clearly the merchandising problems of the industry. Unfortunately identification of these evils did not mean their elimination.

Seaboard R. R., joined Virginia-Carolina in 1897 and rose from shipping clerk to vice-pres.

\* For text, see Appendix XLII.

## REFERENCES

1. C. J. Brand, *Agr. Hist.* 19, 104 (1945).
2. *Chem. Mkts.* 20, 331, 461, 638 (1927).
3. *Chem. Met. Eng.* 34, 323 (1927).
4. *Chem. Mkts.* 23, 320 (1928).
5. *Ibid.* 20, 199 (1927).
6. *Chem. Met. Eng.* 34, 461 (1927).
7. *Ibid.* 710.
8. *Chem. Mkts.* 19, 179 (1926).
9. *Ibid.* 21, 951 (1927).
10. *Ibid.* 22, 641 (1928); S. B. Haskell, to author, Nov. 23, 1946; H. A. Curtis, *ibid.*, Nov. 27, 1946; C. B. Peters, *ibid.*, Nov. 30, 1946.
11. F. E. Bear, *Ind. Eng. Chem.* 20, 1112 (1928).
12. *Ibid.* 673.
13. *Chem. Mkts.* 25, 71 (1929).
14. *O.P.D. Repr.* 66 (Nov. 28, 1937).
15. *Chem. Mkts.* 20, 199 (1927).
16. *Drug Chem. Mkts.* 15, 1987 (1924); *O.P.D. Repr.* 44 (Jan. 5, 1925).
17. *Chem. Mkts.* 19, 1081 (1926).
18. *Ibid.* 20, 198, 250 (1927); *Ind. Eng. Chem.* 18, 685 (1926); *Drug Chem. Mkts.* 18, 245 (1926).
19. *Ind. Eng. Chem.* 19, 537 (1927).
20. *Chem. Mkts.* 20, 127 (1927).
21. *Chem. Met. Eng.* 34, 387 (1927).
22. *O.P.D. Repr.* 72 (Nov. 21, 1927).
23. *Ibid.* 48 (May 27, 1929).

24. *Chem. Mkts.* 25, 75 (1929); 26, 59 (1930).
25. *Chem. Met. Eng.* 35, 509 (1928).
26. *Chem. Mkts.* 24, 409 (1929).
27. *Ibid.* 631.
28. *O.P.D. Repr.* 50 (Jan. 13, 1930).
29. J. B. Faust, *Ind. Eng. Chem.* 19, 276 (1927).
30. P. F. Holstein, *ibid.* 12, 290 (1920); Curtis, *op. cit.*
31. *Drug Chem. Mkts.* 16, 951 (1925); 17, 1735 (1925).
32. *Chem. Mkts.* 20, 121, 551 (1927).
33. *Chem. Met. Eng.* 34, 326 (1927).
34. *Chem. Mkts.* 19, 769 (1926).
35. *Ibid.* 20, 746 (1927).
36. *Ibid.* 22, 189 (1928).
37. Haynes, *Chemical Pioneers*, p. 82.
38. *Drug Chem. Mkts.* 18, 11, 161 (1926); *O.P.D. Repr.* 15 (July 30, 1928); see also Chap. 6.
39. F. G. Keenen, *Ind. Eng. Chem.* 22, 1378 (1938); *O.P.D. Repr.* 17 (July 30, 1928); Barrett Co. memo to author.
40. R. S. McBride, *Chem. Met. Eng.* 36, 592 (1929).
41. F. M. Becket, Hearings Agr. & Forestry Comm. (S. 68:1) on Muscle Shoals, May 12, 1924, p. 830.
42. V. H. Kalish, *Ind. Eng. Chem.* 20, 9 (1928); C. J. Brand, Hearings Agr. & Forestry Comm. (S. 69:1) on Muscle Shoals (S. 2147, etc.), Feb. 19, 1926, p. 171.
43. J. W. Turrentine, Hearings Agr. & Forestry Comm. (S. 68:1) on Muscle Shoals, May 19, 1924, p. 1046.
44. Hearings Mil. Aff. Comm. (House 69:2) & Agr. & Forestry Comm. (S. 68:1, 69:1, 69:2, 70:1, 71:1) on Muscle Shoals.
45. C. C. Williams, Hearings Agr. & Forestry Comm. (S. 68:1) on Muscle Shoals, May 2, 1924, p. 545.
46. *Ibid.* p. 26.
47. E. H. Hooker, *ibid.* p. 53; A. H. Hooker, *ibid.* p. 200.
48. E. R. Welles and C. T. Mitchell, *Elec. World* 73, 677 (1919).
49. Hearings Agr. & Forestry Comm. on Muscle Shoals, (S. 68:1) Apr. 8, 1924, p. 98.
50. *Ind. Eng. Chem., News Ed.* 7 (Mar. 10, 1925), 7 (Apr. 10, 1925); *Drug Chem. Mkts.* 16, 1027 (1925); *Chem. Met. Eng.* 32, 462 (1925); *O.P.D. Repr.* 44 (Mar. 30, 1925).
51. *Ind. Eng. Chem., News Ed.* 7 (Dec. 10, 1925).
52. *Ibid.* 6 (Dec. 20, 1925); *Drug Chem. Mkts.* 17, 1597 (1925).
53. *Drug Chem. Mkts.* 18, 1078 (1926).
54. *Ibid.* 1230.
55. *Chem. Mkts.* 20, 51, 136, 147, 373, 444 (1927).
56. *Ibid.* 49; 21, 858 (1927); *O.P.D. Repr.* 66 (Jan. 17, 1927).
57. *Chem. Met. Eng.* 34, 123, 185 (1927); *Chem. Mkts.* 20, 212 (1927).
58. C. H. Gray, Hearings Agr. & Forestry Comm. (S. 70:1) on Muscle Shoals, Jan. 27, 1928, p. 24.
59. Curtis, *op. cit.*; *Chem. Mkts.* 23, 610 (1928).
60. *Ibid.* 22, 513 (1928).
61. *Ibid.* 24, 633 (1929); 26, 515, 621 (1930).
62. *O.P.D. Repr.* 20 (Oct. 21, 1929).
63. *Drug Chem. Mkts.* 12, 141 (1923).
64. W. C. Moore, *Trans. Am. Electrochem. Soc.* 48, 295 (1925).
65. E. J. Fox and C. W. Whittaker, *Ind. Eng. Chem.* 16, 1044 (1924).
66. *Drug Chem. Mkts.* 15, 695 (1924), 18, 1154 (1926); *Chem. Mkts.* 20, 370, 801 (1927), 21, 6 (1927); *Chem. Met. Eng.* 31, 372 (1924), 34, 125, 386 (1927); *Ind. Eng. Chem.* 18, 614 (1926).
67. *Chem. Mkts.* 20, 549, 629, 950 (1927), 21, 47 (1927); *Chem. Met. Eng.* 34, 266 (1927); *O.P.D. Repr.* 21 (Apr. 11, 1927).
68. *Chem. Mkts.* 24, 183 (1929); *O.P.D. Repr.* 72 (Jan. 16, 1928).
69. *Chem. Mkts.* 24, 289 (1929).
70. Co. memo to author.
71. *O.P.D. Repr.* 20 (June 7, 1926); *Chem. Mkts.* 19, 188 (1926).
72. *Chem. Mkts.* 26, 73 (1930); Co. memo to author.
73. Co. memo to author.
74. J. E. Teeple, *Chem. Met. Eng.* 35, 47 (1928).
75. *Ind. Eng. Chem.* 19, 318 (1927).
76. G. W. Stocking, *Chem. Mkts.* 28, 247 (1931).
77. *Drug Chem. Mkts.* 12, 78 (1923).
78. *Ibid.* 16, 1179 (1925).
79. *O.P.D. Repr.* 47 (Oct. 7, 1929);

- Chem. Mkts.* 25, 192 (1929); *Ind. Eng. Chem., News Ed.* 7 (Aug. 20, 1930).
80. G. R. Mansfield, *Ind. Eng. Chem.* 15, 494 (1923); H. W. Hoots, *Geol. Surv., Bull. No. 780B* (1925); *Min. Ind.* 1923, 556; Turrentine, *Potash*, p. 162.
  81. E. P. Schoch, to author, Dec. 9, 1946; *Chem. Mkts.* 22, 530 (1928), 23, 110, 386, 387 (1928); Stocking, *ibid.* 28, 369 (1931).
  82. Hearings Agr. & Forestry Comm. (S. 68:1) on S. 1925, Apr. 4-5, 1924.
  83. *Min. Res.* 1923, II, 188; *Chem. Met. Eng.* 30, 881 (1924), 34, 138 (1927); *Chem. Mkts.* 19, 354 (1926); *Ind. Eng. Chem.* 19, 654 (1927).
  84. *Chem. Mkts.* 19, 997 (1926), 20, 121, 222 (1927), 22, 361 (1928); *O.P.D. Reprtr.* 21 (Aug. 29, 1927); *Ind. Eng. Chem., News Ed.* 15 (Nov. 10, 1926); *Chem. Met. Eng.* 34, 324 (1927), 35, 43 (1928).
  85. J. S. Wroth, *Bur. Mines, Bull. No. 316* (1930); H. M. Albright, to author, Nov. 20, 1946.
  86. Storch and Clarke, *Bur. Mines, Repts. of Investigations, No. 3002* (1930); Storch, *Ind. Eng. Chem.* 22, 934 (1930); *O.P.D. Reprtr.* 55 (Oct. 7, 1929).
  87. *Drug Chem. Mkts.* 18, 1055 (1926); *Chem. Mkts.* 21, 891 (1927).
  88. United States Potash Co. prospectus, Jan. 14, 1937, p. 4 & memo to author, 1946; Stocking, memo to author; Mansfield and W. B. Long, *Am. Inst. Min. Met. Engrs., Tech. Pub. No. 212* (1929); Wroth, *op. cit.*; *O.P.D. Reprtr.* 21 (Apr. 12, 1926); *Chem. Mkts.* 19, 1290 (1926).
  89. *Chem. Met. Eng.* 34, 468 (1927).
  90. *Ibid.* 36, 412 (1929).
  91. Curtis, *Am. Fertil.* 64, No. 13, 73 (1926); F. E. Bear, *Ind. Eng. Chem.* 20, 65, 1112 (1928).
  92. *Chem. Mkts.* 19, 261 (1926).
  93. *Ibid.* 28, 75 (1931).
  94. *O.P.D. Reprtr.* 21 (Dec. 13, 1926), 23 (Dec. 20, 1926); *Chem. Met. Eng.* 33, 770 (1926); *Chem. Mkts.* 19, 1346 (1926).
  95. *Drug Chem. Mkts.* 18, 700 (1926); *Chem. Mkts.* 19, 358, 440 (1926), 20, 810 (1927).
  96. *Chem. Mkts.* 20, 988 (1927); 21, 632, 644 (1927).
  97. *Ibid.* 23, 386, 390 (1928).
  98. *Ibid.* 25, 295, 517 (1929), 26, 140 (1930); *O.P.D. Reprtr.* 64 (Apr. 22, 1929); *Com. Fin. Chron.* 4010 (June 15, 1929).
  99. *Chem. Met. Eng.* 29, 683 (1923); *Drug Chem. Mkts.* 13, 1103 (1923).
  100. *Drug Chem. Mkts.* 17, 421 (1925); *Chem. Mkts.* 19, 274, 283 (1926).
  101. O. F. Smith, to author, Dec. 5, 1946; *Chem. Mkts.* 21, 328 (1927).
  102. *Chem. Mkts.* 21, 271 (1927).
  103. *Chem. Met. Eng.* 36, 358 (1929).
  104. *O.P.D. Reprtr.* 21 (June 15, 1925); *Chem. Mkts.* 16, 875 (1926), 17, 20 (1925).
  105. Brand, to author, Dec. 18, 1946; *O.P.D. Reprtr.* 22 (Jan. 17, 1927), 66 (Apr. 11, 1927); *Chem. Mkts.* 20, 203 (1927); *Chem. Met. Eng.* 34, 75, 125 (1927).

## Chapter 20

### NEW PEST-CONTROL CHEMICALS

NEW ORGANIC CHEMICALS TESTED AS INSECTICIDES, FUNGICIDES, FUMIGANTS, AND SEED DISINFECTANTS—CAMPAIGN AGAINST BOLL WEEVIL, GYPSY MOTH, ETC., WITH ARSENICALS AND FLUOSILICATES—INTERNATIONAL COPPER WAR WEAKENS U. S. FUNGICIDE MARKET—BELGIAN CONGO BECOMES WORLD COPPER HEADQUARTERS—HYDROCYANIC FUMIGATION IN CITRUS INDUSTRY—UNBALANCED SUPPLY AND DEMAND HARASSES INSECTICIDE MAKERS; MERCHANDISING IMPROVED, PACKAGING SIMPLIFIED.

ETHYLENE OXIDE, chloropicrin, Semesan (hydroxymercurichlorophenol), and Lethane (aliphatic thiocyanates) came on the market as insecticides and fungicides during the 1920's, another example of the diversified use of organic chemicals characteristic of these years. These new pesticides and seed disinfectants were the rewards of a new type of research that went beyond painstaking investigation of the reactions of a new compound with an eye to its possibilities in synthesis. Equipped with all sorts of apparatus, from miniature papermaking machines to breeding cages for bean beetles, what might be called "industrial clinics" became an annex to chemical laboratories. Tests carried on here and in the mills and factories of friendly customers were broadened in scope and made intensely practical. By the most effective means, actual demonstration, this cooperative work spread the gospel of research to many establishments where its value had been rated subzero.

The search for new pesticides followed two lines of investigation: the deliberate synthesis of probable insecticides, fungicides, and fumigants and the cut-and-try toxicity-testing of promising organic compounds. Starting with the knowledge that nicotine, a popular and valuable contact insecticide, is chemically 1-methyl-2-(3-pyridyl)-pyrrolidine, the Department of Agriculture laboratories tested a great number of the derivatives of pyridine, pyrrolidine, and aliphatic amines against aphids, and among the 25 dipyridyl compounds found the most toxic to be neonicotine, 2-(3-pyridyl)-piperidine.<sup>1</sup> From the Dow Chemical Company, Edgar C. Britton and W. H. Williams \* patented butylpyrrolidine† as an insecticide, whose water-soluble sulfate was

\* Like Britton, Williams has been with Dow since 1920 and is one of its 6 production mgrs. in charge of phenol, aniline, and other coal-tar compounds. See also p. 216.

† U. S. Pat. 1,748,633 (1930).

demonstrated to be exceedingly effective against aphids, red spiders, and other pests. Aminoisobutyronitrile was patented for the same purpose by W. Moore of the American Cyanamid Company.\* At the Bureau of Chemistry and Soils, Ruric C. Roark † and R. T. Cotton tested 21 aliphatic chlorides as fumigants,<sup>2</sup> and learned that a mixture of three parts ethylene dichloride and one part carbon tetrachloride by volume most satisfactorily met these requirements.

While these organic areas were being explored, the insecticide industry was not enjoying the good times ordinarily associated with the 1920's. Most of its important products were chronically overproduced, while the purchasing power of the American farmer was steadily declining. Competition was sharp and the inherent infirmities of the agricultural insecticide market were magnified. Of necessity insecticide demand is seasonal, yet it is sufficiently large to require the advance manufacture of stocks which must be located on the spot in widely scattered consumption areas. Despite the growing use of controls, the country's average financial loss due to insect depredations and fungus diseases was estimated<sup>3</sup> at over \$1,000,000,000. Few growers or orchardists used sufficient chemical protection, and thousands used none at all. Not being convinced of the profitableness of pest control, the average farmer neglected prevention and bought his chemical weapons only after serious infestation. These buying habits literally turned over control of insecticide demand to the vagaries of nature—the weather, the bird population, and all the other chancy elements of environment upon which the “bug crop” depends. ‡ The commercial history of the big-tonnage pesticides becomes therefore an account of a guessing match among the larger manufacturers. As they predicted their estimates more or less upon identical data or similar dreams, the unbalance of supply and demand was frequently serious.

An awesome spectacle of these market gymnastics is displayed by arsenic, the backbone of many insect-control chemicals. Lead arsenate and Paris green (copper acetoarsenite) had been joined in 1918 by calcium arsenate § as a weapon against the “billion dollar bandit,” Hudson Maxim's picturesque name for the cotton boll weevil.<sup>4</sup> This new insecticide had created a demand for white arsenic ( $As_2O_3$ ) which ex-

\* U. S. Pat. 1,761,144 (1930).

† A tireless investigator and prolific writer, Roark is the recognized insecticide authority of the Dept. Agr., with which he has been connected since 1923. Previously he was with U. S. Sanitary Specialties Corp., Chicago, and 5 yrs. with General Chemical. He was born in Ky., 1887, and holds an A.B., U. Cincinnati; A.M., U. Ill.; Ph.D., Geo. Wash. U.

‡ For discussion of insecticide markets, see L. S. Hitchner, *Chem. Met. Eng.* 37, 62 (1930); Haynes, *Chemical Economics*, p. 58.

§ For U. S. production of these insecticides, see Appendix XLIII.



ceeded the customary supplies then imported and led to its recovery at lead and copper refineries in this country.\* Short stocks and a heavy weevil infestation in 1922 sent the price of calcium arsenate to famine levels, and the year ended with a rather frantic conference of government officials, arsenic producers, and manufacturers of insecticides, with threats of a Congressional investigation. †

The next year, 1923, stripped naked all the evils of the arsenic-marketing situation. Tempted by the high prices of the previous season, producers of both white arsenic and calcium arsenate increased their output and new producers embarked in this field. Cotton planters held off buying and at the last minute stampeded to save their crop from a late, sudden infestation. Though the manufacturers' price of calcium arsenate ranged between 12 cents and 17 cents a pound, some frantic growers paid local dealers and speculating brokers as high as 30 cents and even 40 cents a pound,<sup>5</sup> a spread that sent the farmer and his friends to Washington yowling for help. Again the year ended with a government-sponsored conference in New York, December 7, which, if nothing else, aired contradictory facts and conflicting opinions—both from the highest authority—which confused everyone and promoted debate rather than decision.<sup>6</sup>

During this particularly critical insecticide year, the basic raw material, white arsenic, which was mainly a by-product from copper and lead-smelting operations, production ‡ reached a then all-time high of 14,902 short tons.<sup>7</sup> Nine-tenths of this supply came from three companies: the largest, the American Smelting & Refining Company, with two arsenic plants at Tacoma and near Denver; the U. S. Smelting, Refining & Mining Company, working its own lead ore at Midvale, Utah, and also buying crude white arsenic from which it produced arsenate and the weed killer sodium arsenite; and the Anaconda Copper Mining Company, recovering both crude and refined arsenic from its current flue dust and also working up a large waste pile of arsenical dusts. Along with these, the International Smelting & Refining Company produced crude arsenic from a ten-year accumulation of dust at its copper-lead plant near Tooele, Utah. The remaining 10 per cent of the output came from four new plants deliberately operating for arsenic. These were the Toulon Arsenic Company; the Jardine Mining Company;

\* According to the Census, the total production of arsenic oxides increased from some 33,000,000 lb. in 1923 to about 43,000,000 lb. in 1929. See also Vol. III, p. 115.

† Vol. III, p. 117.

‡ "During 1923-29 the U. S. consumed from 3,000-6,000 tons of crude arsenic converted to sodium arsenite weed killer. This quantity was statistically ignored in the Government reports." (R. N. Chipman, to author, Dec. 3, 1946.)

Salt Lake Insecticide Company; and the National Chemical Company. The last two companies manufactured calcium arsenate.

High arsenic prices encouraged additional direct production and in Utah the Midvale and Murray smelters installed new roasters. The Butters' cyanidation plant at Martinez, California, was converted for arsenic recovery and the Arsenic Products & Refining Company in Nevada, also controlled by the Chipman Chemical Engineering Company, started operation. In South Dakota the Keystone Arsenic Company began plant construction, while in Arkansas Valley, Colorado, a new operation was planned by the Colorado Insecticides, Inc. Refiners of white arsenic said frankly that if the price dropped below 9 cents—the average price this year was  $9\frac{1}{2}$  cents—it would not pay to recover this by-product unless compelled to do so by a nuisance injunction.

Both production and price of calcium arsenate were very much influenced, and not to the benefit of the ultimate consumer, by quasi-public operations. The state of Georgia the year previously had purchased this insecticide and distributed it at cost to the growers.\* The Commissioner of Agriculture announced that Georgia had purchased 100,000,000 pounds of calcium arsenate to be delivered over the next five years at the rate of 20,000,000 pounds annually, at a price of 10 cents a pound.<sup>8</sup> The National Gold Arsenic Corporation was created to fill this contract in a plant to be located in Georgia working raw material from the state of Washington. The manufacturers of arsenate roundly denounced these arrangements as a political deal at an impossibly low price which could only rouse false hopes in the minds of the farmers. In August the new corporation was reported to be building a plant. In November the Commissioner wrote Georgia cotton planters, admitting that 10-cent arsenate was a will-o'-the-wisp, since the National Gold Arsenic Corporation had been unable to finance its proposed operation, and that a new contract was being negotiated on the sliding scale of 10 cents for the first 1,000,000 pounds, 11 cents for the next 1,000,000, and 12 cents for the last 3,000,000 pounds.<sup>9</sup> The following month Georgia contracted with the Nitrate Agencies Company of Bayonne, New Jersey, for 1,000,000 pounds of calcium arsenate for 1924 delivery at  $11\frac{1}{2}$  cents a pound, a public confession that the National Gold Arsenic proposition had collapsed without delivering a pound of insecticide.<sup>10</sup>

These excursions of the state of Georgia into the arsenate industry

\* See Vol. III, p. 117. It is to be noted that the state's purchase from Sherwin-Williams at 9¢ was for surplus material carried over from the short-consumption season of 1921. As there was no quantity limit to the contract, the manufacturer was compelled to purchase additional 1,500,000 lb. at 14¢ to fulfill its obligation.

ended in 1926 in a political brawl. Charging that J. J. Brown, the Commissioner of Agriculture, had used cheap arsenate to build up a personal political machine, the legislature refused to appropriate the revolving fund \* for the purchase and sale of calcium arsenate, and the state Attorney General ruled forbidding him to use other funds for this purpose.<sup>11</sup>

All this noisy clamor about 10 cent arsenate, which induced many farmers to hold off their purchases, was ably seconded by the American Cotton Growers' Association organized in January 1923 to wage war on the weevil by an educational campaign and cooperative buying of arsenate.<sup>12</sup> It announced shortly that it had raised \$2,500,000 and proposed immediately to produce calcium arsenate on a large scale and to perfect cheaper, more direct methods of distribution.<sup>13</sup>

The South's imperative need for more and more arsenic, coupled with the prospect of greater use of electric power, inspired Thomas W. Martin, † who in 1920 had become president of the Alabama Power Company, to explore the possibilities of an electrolytic process for the oxidation of white arsenic.<sup>14</sup> Under A. M. Kennedy, the Alabama Power Company engineer who originally made this suggestion, preliminary work was started at the Federal Phosphorus Company at Aniston. Later the research was moved to Alabama University and Stewart J. Lloyd ‡ put in charge. Still later the General Electric Company § cooperated actively in the development of a practical process. ¶ The Gulf States Chemical & Refining Company was reorganized to operate this new electrolytic process and an installation was made in January 1924, with a capacity of 20 tons daily.<sup>16</sup> At the same time another process, ¶ which had been falteringly operated by the Salt Lake Insecticide Company, was overhauled when the American Smelting &

\* "The Riches, Piver & Co. took a note for the state's obligation signed by the state Entomological Dept. This note was not a legal obligation. However just a few months ago (1946) the legislature passed an appropriation paying the obligation. Among the companies involved were Lucas Kil-Tone, Commercial Chemical, and Riches, Piver, the latter being the one that developed and produced the first calcium arsenate." (L. S. Hitchner, to author, Dec. 19, 1946.)

† A public-spirited, chemically minded leader in the development of Southern resources, Martin was instrumental in organizing the Southern Research Inst., 1944, of which he is chmn. He was born in Scottsboro, Ala., Aug. 13, 1881; trained in law at U. Ala.; and in 1912 became atty., Alabama Power Co. Dir. of numerous power and industrial corporations, and regional vice-chmn. of Comm. Econ. Development, he has been decorated Officier d'Académie (France), and holds hon. LL.D.'s from Ala. and Cumberland U.

‡ Another constructive friend of chemical developments in the South, Lloyd has taught at U. Ala. since 1909, and as State Geologist and consultant to many companies, has made important contributions. He was born in Canada, 1881; A.B., Toronto, 1904; M.S., McGill, 1906; Ph.D., Chicago, 1910.

§ U. S. Pat. 1,517,516 (1924).

¶ See Vol. III, p. 119.

Refining Company took over this plant for a six months' experimental period.<sup>17</sup>

This ill-starred comedy of errors that disappointed the expectations of consumers turned during the next two years into a melancholy tragedy for the producers. Although a marked decline in price kept the high-cost operations idle during most of 1924, production of white arsenic was greater than the year previous, so that the decline in demand left considerable stock awaiting conversion into insecticides.<sup>18</sup> The output of calcium arsenate also increased 19.6 per cent, 18 establishments making a total of 43,625,000 pounds, while lead arsenate supplies increased 38.5 per cent to a total of 21,004,000 pounds, also from 18 producers.<sup>19</sup> The boll weevil failed to appear, thanks to a dry summer, although it seemed to the manufacturers that this pest was deliberately rigging the market.

One conspicuous event of the year 1924 was the start of comprehensive tests of boll weevil control by the Chemical Warfare Service on a special appropriation from Congress.<sup>20</sup> Over 1,000 possible poisons and 2,500 of their combinations were tried out in a series of large field tests in Florida, Georgia, and South Carolina during 1927. Two chemicals were eminently successful, calcium arsenate containing only about 20 per cent arsenic (compared with 40 per cent in the commercial product) and sodium fluosilicate, which had been extensively studied at Knoxville, Tennessee.

In 1926 the refiners of white arsenic were reduced to the U. S. Smelting, Mining & Refining Company, the American Smelting & Refining Company, the Anaconda Copper Mining Company and its subsidiary, the International Smelting & Refining Company. In view of the heavy carry-over, these firms all avoided so far as possible the smelting of arsenic-bearing ores.<sup>21</sup>

While calcium arsenate sunk deeper into the slough of overproduction, lead arsenate picked up, due to extended uses, notably in the U. S. Department of Agriculture's campaign against the gypsy moth in New England, for which the Chipman Chemical Engineering Company supplied 71½ tons.<sup>22</sup> New uses for white arsenic were also encouraging: in the production of plate glass for automobile windshields and windows, and in the preservation of wood, which was investigated jointly by Anaconda Copper and Western Union Telegraph.<sup>23</sup> At the Mellon Institute colloidal arsenious oxide was found to be a superior rodent poison, without the fire hazard of phosphorus and more quick and certain in its results than strychnine or white arsenic.<sup>24</sup> Another arsenical, sodium arsenite, was credited with practically having eliminated the scourge of Texas fever by destroying the cattle ticks causing the disease.<sup>25</sup>

Two hurtful effects of arsenical insecticides—their tendency to burn tender foliage and the possible danger of poisoning from a residue left on fruits and vegetables—were seriously investigated at this time. British authorities, when they condemned shipments of American apples, forced an issue upon the enforcement officials of our Pure Food Laws,<sup>26</sup> and the General Chemical Company made a constructive contribution to the foliage-burning problem when it developed and put on the market basic lead arsenate.<sup>27</sup>

While the uses of arsenicals were thus multiplying and becoming more essential in our agricultural economy, the domestic supply of crude white arsenic was fast drying up. By 1929 all production directly from ores in the United States, except by Anaconda, had ceased. The price of imported material, which was duty-free, declined till it did not pay lead and copper smelters to recover the by-product. Again this country was dependent upon foreign supplies for a chemical element of growing importance, due to the fact that extraordinary mining activity in Mexico, Canada, and Japan, our principal sources of arsenic, had been supplemented by a considerable new output from the Boliden smelters in northern Sweden. The whole sad story of the rise and fall of American arsenic was told to the Ways and Means Committee holding tariff hearings, by W. C. Bacorn<sup>28</sup> of the Jardine Mining Company, who warned that sudden, great demand for any of the arsenicals would catch us dolefully short of the essential raw material. The American producers asked for a 4-cents-a-pound duty, a plea that was quite futile against the Congressional taboo of any tariff on any agricultural chemical. So arsenic and its salts remained on the free list in the Hawley-Smoot Tariff.

During the late twenties the manufacture of calcium arsenate had continued on a growing scale, and in 1929 there were 21 producers with a yearly capacity of 25,000,000 pounds.<sup>29</sup> One of the more important of the new makers was the National Chemical Company of Pittsburg, California, financed by the Sloss interests, which came into production in 1925 under the operating managership of William B. Scheffer, formerly with Hemingway, Sherwin-Williams, and the Nitrate Agencies.<sup>30</sup>

The copper fungicides\* had no such fantastic price history during the twenties as did the arsenicals. From 1920 until May 1926 the market was oversupplied and the price weak. Then, as the market finally began to tighten up, it was noted that copper sulfate was one of the few chemicals selling below the 1921 quotations.<sup>31</sup> This persistent weakness,

\* Though modest quantities of copper carbonate are used in an ammonical solution, the important one is the sulfate, used directly as a spray and dust, but chiefly in Bordeaux mixture (copper sulfate and lime, 4 lb. each in 50 gal. water).

which kept the price of the salt proportionately lower than that of the metal, was influenced not only by overproduction, but also by a trade war in the international market and the selling policy of the larger American producers who were determined to keep the American price low. Strengthening of the market resulted from new uses and a truce in the international trade war. This was effected in 1927 by the organization of the British Copper Sulphate Association which recognized that Italy had become self-sufficient for its big vineyard needs.<sup>32</sup> The new uses for copper sulfate were its substitution for salt in grounding high-tension electrical equipment, for killing algae in city-water supplies, and as a reagent in the selective flotation of zinc ores.<sup>33</sup> An important new use, as an antifouling agent for ship-bottom paints, was discovered for cuprous oxide which was produced commercially in this country in 1926 after a long series of tests by Rohm & Haas, in direct response to the approval of the Navy Department.<sup>34</sup> In 1929 the company filed a brief, asking a 40 per cent ad valorem duty, claiming that it had a productive capacity sufficient to meet the requirements of this country, which were estimated at between 400,000 and 500,000 pounds per annum.<sup>35</sup> A 35 per cent duty was levied, a 10 per cent increase over the Fordney-McCumber rate.

While copper salts were distinguishing themselves by breaking the strong price-bond that connects them with the metal, copper itself passed a crucial turning point in its history. To meet new demands from the automobile and radio industries, domestic production of the red metal in 1923 set new highs\* which exceeded all previous records, except the war year, 1917. The total output continued to rise year by year, reaching 3,993,000,000 pounds in 1929.<sup>36</sup> During 1923 an event like "a little cloud out of the sea, no larger than a man's hand," forecast the coming deluge of foreign copper which was to wrest from American production supremacy in this metal. Walter H. Weed† noted the unusual expansion of copper production in Chile and that year Anaconda bought the Chile Copper Company for \$150,000,000.<sup>37</sup>

Production of copper had been artificially stimulated by the Pittman Act‡ during 1921 and 1922, by giving copper producers an opportunity

\* 2,802,000,000 lb. of which 829,000,000, or roughly a third, was exported.

† During the 1920's Weed, an outstanding consulting geologist, wrote the copper chapters of *Min. Ind.* He was ed., *Mines Handbook*, 1911-25, and conducted geol. surveys of the Yellowstone Park and in Montana, Mexico, Peru, Ecuador, and Serbia. Born in St. Louis, 1862, he got his M.E. from Columbia, 1883.

‡ In 1918 this Act authorized the Secy. of Treas. to sell not more than 350,000,000 silver dollars held in trust against the silver certificates, but specified that he should purchase enough silver from American mine owners at \$1 an oz. to replace the coins melted and sold as bullion. Between Apr. 1918 and Oct. 1919, \$260,000,000 in silver bars were sold at a profit of from 25-50%, but in 1921, when the price of silver dropped, mine owners demanded resumption of silver coinage at the \$1 price, which resulted

to make a profit on by-product silver. But this spelled overproduction, the cause of their worst troubles.<sup>38</sup> Growing consumption eased this pressure, and during that record-breaking year of 1923, the Utah Copper Company was absorbed by the Kennecott Copper Corporation, and Calumet & Hecla took over the Ahmeek, Allouez, Centennial, and Osceola Mining Companies into the reorganized Calumet & Hecla Consolidated Copper Company.<sup>39</sup>

The foreign storm was brewing. Production in Chile, chiefly from the American-owned Guggenheim and Anaconda properties, advanced rapidly. In 1926 the growing importance of the Katanga mines in the Belgian Congo was tacitly recognized by the formation of an international cartel, Copper Exporters, Inc. Organized originally as a Webb-Pomerene corporation, it included most of the world copper production, with the notable exception of the British Metals Corporation, agents of the Katanga mines, which withdrew after the sale of the Belgian Congo copper was placed with cartel agencies.<sup>40</sup> In 1928 the discovery that the Frood nickel mine in Canada contained large percentages of copper strengthened that country's producing position, and in 1929 the opening of the railroad from the West Coast of Africa to the heart of the Katanga district established the Congo as world headquarters of copper production.<sup>41</sup> This year foreign producers withdrew from the American-organized Copper Exporters, a gesture indicating the close of American copper primacy in world markets. In 1932 Congress wrote a postscript when it placed a 4 cents-a-pound duty on copper.

The world picture had changed, but in spite of the loss of exports the copper situation in this country continued to improve because of growing demand. In 1927 an electrolytic refinery was built at El Paso by the Nichols Copper Company, now a subsidiary of the Phelps Dodge Corporation, with a capacity of 100,000 tons annually and costing \$3,000,000. The new operation was financed by the sale of stock to Phelps Dodge and the Calumet & Arizona Mining Company, whose ores it reduced.<sup>42</sup> To encourage the uses of copper, the Copper Institute was formed in New York, November 10, 1927, in collaboration with the Copper & Brass Research Association and the American Bureau of Metal Statistics.<sup>43</sup> The president of Anaconda, C. F. Kelley, was chairman of the executive committee, F. H. Brownell of American Smelting & Refining was president, S. Birch of Kennecott Copper and William Douglas of Phelps Dodge were vice-presidents, and the executive secretary and treasurer was R. R. Eckert.\*

in the reestablishment of a silver hoard of \$500,000,000, a subsidy to the silver miners of about 40¢ on the dollar at a cost of \$80,000,000 to the country.

\* Excepting Eckert, these officers and the following were on the exec. comm.: R. I.

Returning to the insecticides, the market continued throughout the twenties to be harassed by overproduction, extreme variation in seasonal sales, and fantastic price fluctuations.<sup>44</sup> Yet amid this commercial turmoil there was surprising progress. In fields and orchards new formulas and improved methods of application, notably in dusting and spraying, were making control techniques much more effective.<sup>45</sup> The replacement of kerosene by oil and soap emulsions was a real advance in which the California Spray Chemical Company led the vanguard. In dusting, the Niagara Sprayer & Chemical Company, which specialized also in dusting machinery, played a similar role. It made monohydrated copper sulfate, then recently discovered as a dusting material, and the fused bentonite-sulfur product patented \* by Henry W. Banks, 3rd, of Loomis, Stump & Banks.<sup>46</sup> Finely divided sulfur came into general use at this time, especially to control apple scab, and the General Chemical Company replaced the so-called "atomic" sulfur, previously sold in paste form, with "dritomic" sulfur, an improved wettable sulfur in dry form, developed and commercially produced in 1924 at its Baltimore works.<sup>47</sup>

Another innovation was the use of various silicofluorides. As early as 1896, Higbee had patented † fluorides, fluosilicates and fluosilicic acid as insecticides,<sup>48</sup> and several of these compounds had been used to control the European earwig, grasshoppers, and cutworms, but not until 1924, when the first extensive experiments were carried on by the Tennessee Agricultural Experiment Station, did these fluorine compounds attract wide attention in this country.<sup>49</sup> The original tests emphasized sodium fluosilicate as a substitute for arsenate in control of the bean beetle and the boll weevil, but subsequent researches brought further recommendations for cryolite (sodium-aluminum fluoride) and barium fluosilicate.<sup>50</sup> Sodium silicofluoride, a by-product in the manufacture of fertilizer superphosphates, was offered promptly, and in 1925 the Oconee Alkali & Chemical Company of Athens, Georgia, and the Southern Alkali & Chemical Company of Savannah, petitioned the Tariff Commission to increase the duty. When hearings were held, ‡

Agassiz, Calumet & Hecla; J. H. Anderson, United Copper; G. R. Campbell, Calumet & Arizona; C. W. Nichols, Nichols Copper; and L. Vogelstein, American Metal. The members of the Inst. were: Anaconda Copper, American Smelting & Refining, American Metal, Andes Copper Mining, Calumet & Arizona Mining, Kennecott Copper, Nevada Consolidated Copper, Phelps Dodge, Braden Copper, Calumet & Hecla Mining, Chile Copper, Cananea Consolidated Copper, Consolidated Copper Mines, Greene-Cananea Copper, Inspiration Consolidated Copper, Mother Lode Coalitions Mines, New Cornelia Copper, Nichols Copper, International Smelting & Refining, North Butte Mining, United Verde Copper, Utah Copper, and Walker Mining Companies.

\* U. S. Pat. 1,550,650 (1925).

† Brit. Pat. 8,326.

‡ Supporting increased duty at these hearings were R. M. Keating, Baugh Chemical



it was brought out that American consumption was in the neighborhood of 5,000,000 pounds, and that imports, chiefly from Denmark and Holland, had recently increased from 2,000,000 to 3,000,000 pounds. American costs, as revealed by the Tariff Commission's investigation, were 5.324 cents a pound, while Danish and Dutch costs were 3.0599 cents. The Tariff Commission recommended<sup>51</sup> a change in the duty to 25 per cent ad valorem on the basis of the American selling price and the President approved this increase, August 31, 1928.

Commercial manufacture of liquid hydrogen cyanide for the fumigation of citrus trees began in the early twenties.<sup>52</sup> Because of the transportation hazard, this new branch of the industry established itself largely in California, where the California Cyanide Company was organized in 1923.<sup>53</sup> It was backed jointly by a group of Californians led by Frederick W. Braun \* of Braun-Knecht-Heimann Company and the Braun Corporation, chemical jobbers of San Francisco and Los Angeles, and the Air Reduction Company. A third each was subscribed by the California group, by shareholders of Air Reduction, and by the Air Reduction Company itself. A plant was built at Cudahy near Los Angeles, and the officers were Braun, president; John Pike, vice-president and general manager; J. D. Neuls, in charge of field service; and R. W. Poindexter, in charge of the laboratory.

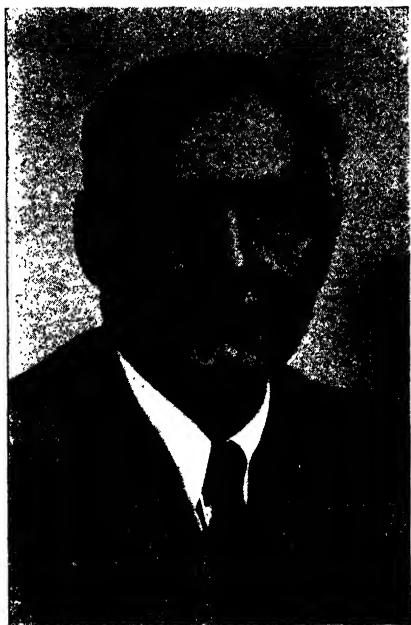
Increasing use of this most useful but highly toxic fumigant prompted the Public Health Service to seek a substitute, and in 1923 the Chemical Warfare Service was called into this research. Chloroacetophenone was tried but found too persistent, and later cyanogen chloride was added to hydrogen cyanide to serve as a warning agent.<sup>54</sup> More practical were safer methods of generating hydrocyanic acid gas from sodium cyanide and especially the commercial production for this purpose of calcium cyanide,<sup>55</sup> which appeared on the market in 1925 from the Air Reduction Company and the American Cyanamid Company.

From war-gas experience came another fumigant, chloropicrin,† which was offered commercially in 1926 by Innis, Speiden & Company under the name of Larvacide.<sup>56</sup> To avoid the extreme fire hazard of carbon bisulfide as a grain fumigant, the chemists of the Bureau of Chemistry and Soils, in cooperation with the Bureau of Entomology, experimented with a number of aliphatic compounds. They found distinct fumigant values in the methyl and ethyl esters of monochloroacetic acid, and the isopropyl and secondary butyl esters of formic acid mixed with carbon

Co.; J. S. Brodgon and Andrew M. Fairlie, consulting chem.; opposing, John F. Wischhusen, American Fluoride Corp.

\* Braun (1858-1935) was active in the drug trade since 1878 and 10 yrs. later opened the first wholesale drug house, F. W. Braun & Co., south of San Francisco.

† Trichloronitromethane,  $\text{CCl}_3\text{NO}_2$ , first prepared by Stenhouse. [See *Ann.* 66, 241 (1848).]



WILLIAM H. CHARCH



HARRY M. DENT



B. M. MAY



WILLIAM C. SPRUANCE, JR.



EMIL E. NOVOTNY



FRANK H. REICHEL



J. STOGDELL STOKES



ROGER N. WALLACH

tetrachloride.<sup>57</sup> More important was the discovery of the insecticidal action of ethylene oxide by Cotton and Roark,<sup>58</sup> and its even greater toxicity when supplemented by carbon dioxide.<sup>59</sup> This gas mixture of 10 per cent ethylene oxide and 90 per cent carbon dioxide was put on the market by Carbide and Carbon Chemicals Corporation under the trade-mark "Carboxide."

Du Pont began in 1924 the manufacture of Semesan, then consisting of 35 per cent hydroxymercurichlorophenol, which was the first organic mercurial to be made in this country for the disinfection of seeds. Two similar organic mercurials followed in 1926, designed specifically for protecting seed corn against the seed-borne diseases known as diplodia, gibberella, fusarium, and basiporium; and for seed potatoes against rhizoctonia, common scab, and bacterial decay, all previously treated with formaldehyde. In 1928 this branch of du Pont's business was consolidated with a similar branch of Bayer to form the Bayer-Semesan Company\* for the further development of seed disinfectants through du Pont research and under patents licensed to Bayer by Winthrop Chemical, which held United States and Canadian rights to all such inventions of the I.G.<sup>60</sup>

In 1929 Rohm & Haas put on the market Lethane, another group of strictly synthetic insecticides, which were based on aliphatic thiocyanates.<sup>61</sup>

During the twenties, derris root and its active principle, rotenone ( $C_{23}H_{22}O_6$ ), attracted attention. Pyrethrum, as active ingredient in oil sprays to control flies and mosquitoes, was also introduced at this time, and in 1923 Flit † was put on the market by the Standard Oil Company of New Jersey.<sup>62</sup> Also in the household insecticide field the ancient problem of the clothes moth was attacked anew with vigor and from a scientific approach. Early in 1921, the newly organized Mundatechnical Society of America, a group of dry cleaners and dyers, established a fellowship at Mellon Institute to study the problems of their industry, among which was the discovery of a satisfactory mothproofing agent. After exhaustive tests it was announced<sup>63</sup> that cinchona alkaloids alone met the requirements of absence of odor, good adherence to the treated fabric without damage to it, solubility in cheap solvents, lack of toxicity, and economic costs. ‡ The apparent moth-repellent properties of certain coal-tar dyes was observed at the Jeffersonville Depot of the Quartermaster Corps where large quantities of war-surplus woollens were stored,

\* Officers were W. E. Weiss, pres.; J. Warren Kinsman, vice-pres.; E. I. McClintock, secy.; J. B. Eliason, treas.; K. N. Chase, sales mgr.; L. C. Reed, asst. treas.; H. E. Fry, adv. mgr. [See *Chem. Mkts.* 23, 609 (1928).]

† U. S. Trade-Mark 201,907 (1924).

‡ L. E. Jackson and H. E. Wassell, U. S. Pat. 1,615,843 (1927).

and after testing by the Bureau of Standards, a conference \* was called in an effort to work out some practical correlation and to stimulate further investigations.<sup>64</sup> Neither of these well-publicized moth controls proved efficient.

The bad demoralization of the markets for the agricultural insecticides prompted efforts to improve the merchandising system. In 1924 the Agricultural Insecticide & Fungicide Manufacturers' Association was organized, and Ernest T. Trigg † of John Lucas & Company was elected president; Thomas S. Grasselli of Grasselli Chemical Company, vice-president; Harry J. Schnell of the *Oil, Paint & Drug Reporter*, treasurer; and George B. Heckel of the *American Paint Journal*, secretary.<sup>65</sup> At the suggestion of Secretary of Commerce Hoover, who was advocating simplified packaging, a committee of which D. A. Ansbacher was chairman was appointed. This committee recommended some drastic eliminations. For arsenate of lead, it suggested 100, 25, 4, and 1-pound packages, discarding the 200, 50, 10, 6 and ½-pound; for calcium arsenate, 100, 25, 4, and 1-pound, eliminating 200, 50, 10, and ½-pound; Paris green, 300 or 250, optional, 100, 14, 5, 1, and ½-pound, eliminating 56, 28, 2, and ¼-pound; for Bordeaux mixture, 100, 25, 4, and 1-pound, eliminating 200, 50, 10, and ½-pound. These suggestions were timely because a recent reclassification of these insecticides by the Interstate Commerce Commission as Class B poisons required new packaging to comply with the shipping regulations, and while the ideal was not achieved, there was a marked simplification.<sup>66</sup>

These ideas echoed in the household insecticide field when the Insecticide & Disinfectant Manufacturers' Association conferred in Indianapolis, November 17, 1926, with William E. Humphrey of the Federal Trade Commission and M. M. Flannery of the Trade Practice Conferences, and firms ‡ handling 70 per cent of the household disinfectants signed a resolution condemning bribery in the trade.<sup>67</sup>

In the spirit of the 1920's, the incorrigible uncertainties of the insect-

\* Attending were S. M. Rosenberg and A. P. Clausen, Larvex Corp.; J. Bardcke, Newport Chemical; M. H. Goldman, Nat. Assoc. Dyers & Cleaners; H. F. Herrick, Color Lab., Dept. Agr.; R. T. Cotton and E. A. Back, Bur. Entomology; E. E. Waters and W. D. Apple, Bur. Standards; E. H. Ehrman, Navy; Col. J. S. Chambers, QMC; and E. E. Lightfoot, OQMG.

† Now pres. of Nat. Paint, Varnish & Lacquer Assoc., Trigg was with Heath & Milligan Paint Mfg. Co. before going to Lucas.

‡ These firms were Chemo Co., Buffalo; Baird & McGuire of St. Louis and Holbrook, Mass.; Selig Co., Atlanta; West Disinfecting Co., L. I. City; Puritan Chemical Co., Atlanta; C. B. Dolge Co., Westport, Conn.; Huntington Labs., Huntington, Ind.; Frederick Disinfecting Co., Atlanta; International Chemical Co., Chicago; Interstate Sanitation Co., Cincinnati; Corkins Chemical Co., Cincinnati; Worrell Mfg. Co., St. Louis; American Disinfecting Co., Sedalia, Mo.; Robertson Products Co., Chicago; and Rochester Germicide Co., Rochester, N. Y.

ticide market and the unscrupulous competition they fostered might be expected to have promoted a number of mergers. However at the time when the idea of consolidation was most popular in the chemical industry, there were no notable amalgamations in this group. The reason for this was bound up with the demoralization of this market.

Any by-product chemical is apt to be a disturbing element in the sales field. Its supply depends not upon the demand for it, but on the production of another, often commercially unrelated chemical. Its cost may be juggled to justify any selling price. While the principal insecticides were not by-products of other major chemical operations, nevertheless the entire insecticide department of a number of the largest producers was in a sense a by-product, a sideline, not their principal activity. There were certain forthright manufacturers—Chipman, Niagara Sprayer, California Spray, Ansbacher, Interstate, and others—whose success or failure depended on the continuous, profitable sale of insecticides and fungicides. However the dominating producers were paint manufacturers, Sherwin-Williams, Lucas, and Devoe & Raynolds, or fertilizer companies Bowker and Nitrate Agencies, or else Pittsburgh Plate Glass, which owned the "Corona" products. Even among the leading chemical companies in this field—General Chemical, Grasselli, and Dow—these products were by no means the center of their activities. Associated as these products were with the main production of dry colors or heavy chemicals, their makers adopted towards them a by-product mental attitude which certainly did not help to stabilize the market. Furthermore, the men of these divergent industries had variable ideas on almost every phase of business policies. All these contributing factors prevented the formation of mergers.

The weakness of this situation was recognized and just as Pittsburgh Plate Glass handled its insecticides business through a separate Corona Chemical Division and the American Agricultural Chemical Company had kept the Bowker Chemical Company a distinct organization, so John Lucas & Company formed the Lucas Kil-Tone Company to take over its insecticide plant at Vineland, New Jersey,<sup>68</sup> and put its operation in direct charge of C. D. Vreeland and L. S. Hitchner. Nevertheless, the manufacture and sale of insecticides continued throughout the twenties and into the thirties to be so conditioned by unpredictable demand and wavering output that Albert W. Hawkes, at that time in charge of General Chemical Company's sales, bitterly described it as "the snake's tummy of the chemical business."

## REFERENCES

1. C. H. Richardson and H. H. Shepard, *J. Agr. Research* 40, 1007 (1930); C. R. Smith, Richardson, and Shepard, *J. Econ. Entomol.* 23, 863 (1930).
2. *J. Econ. Entomol.* 21, 135 (1928).
3. Sanderson, *Insect Pests*, p. 1.
4. *Drug Chem. Mkts.* 12, 531 (1923).
5. *Min. Ind.* 1923, 52; *Min. Res.* 1923, I, 164; *Chem. Mkts.* 19, 517 (1926).
6. *Min. Ind.* 1923, 51; *O.P.D. Repr.* 19 (Dec. 10, 1923).
7. *Min. Res.* 1923, I, 159.
8. *O.P.D. Repr.* 94 (Aug. 20, 1923).
9. *Ibid.* 19 (Nov. 26, 1923).
10. *Ibid.* 71 (Dec. 17, 1923).
11. *Ibid.* 21 (Sept. 21, 1925); *Drug Chem. Mkts.* 17, 761 (1925).
12. *Drug Chem. Mkts.* 12, 79 (1923).
13. *Ind. Eng. Chem.* 15, 211 (1923).
14. S. J. Lloyd and A. M. Kennedy, *Trans. Am. Inst. Chem. Engrs.* 16, Pt. II, 29 (1924) & *Chem. Met. Eng.* 32, 624 (1925).
15. *Chem. Met. Eng.* 29, 118 (1923).
16. *Drug Chem. Mkts.* 13, 1463 (1923), 14, 405 (1924); E. A. Yates, Hearings Agr. & Forestry Comm. (S. 68:1) on Muscle Shoals, May 16, 1923, p. 978.
17. *Drug Chem. Mkts.* 13, 1247 (1923).
18. *Min. Ind.* 1924, 65.
19. *Ibid.*
20. H. W. Walker and J. E. Mills, *J. Econ. Entomol.* 19, 600 (1926) & *Ind. Eng. Chem.* 19, 703 (1927); A. A. Fries, *Ind. Eng. Chem.* 20, 1080 (1928).
21. *Min. Ind.* 1926, 55.
22. *O.P.D. Repr.* 67 (Nov. 2, 1925).
23. *Min. Ind.* 1926, 62.
24. *Drug. Circ.* 70, 738 (1926).
25. F. C. Holton, *Ind. Eng. Chem.* 18, 932 (1926).
26. *Min. Ind.* 1926, 63.
27. Co. memo to author.
28. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 1, Jan. 1929, p. 227; see also *Min. Res.* 1928, I, 4, 1931, I, 9.
29. Food, Drug & Insecticide Administration, *Ann. Repr.* 1930, p. 17.
30. *Drug Chem. Mkts.* 16, 1179 (1925).
31. *O.P.D. Repr.* 54 (Mar. 26, 1925); *Drug Chem. Mkts.* 18, 1074 (1926).
32. *Chem. Mkts.* 20, 360 (1927).
33. *Min. Ind.* 1924, 177.
34. Co. memo to author; see also H. A. Gardner, *Paint Mfrs. Assoc. of U. S., Tech. Circ. No. 259*, 232 (1926) & *No. 287*, 147 (1926).
35. Hearings Ways & Means Comm., *op. cit.* p. 197.
36. *Min. Res.* 1929, I, 526.
37. *Drug Chem. Mkts.* 12, 145 (1923).
38. J. C. Bailar, Jr., *J. Chem. Educ.* 10, 102 (1933).
39. *Min. Res.* 1923, I, 188.
40. L. Domeratzky, Bur. For. Dom. Com., *Trade Inform. Bull. No. 556*, p. 55; *Min. Ind.* 1926, 156.
41. Bailar, *op. cit.*; Tariff Comm., *Copper*, Ser. 2, Rept. No. 29, p. 25.
42. *Chem. Met. Eng.* 35, 392 (1928); *O.P.D. Repr.* 20 (Sept. 8, 1930).
43. *O.P.D. Repr.* 50 (Nov. 14, 1927).
44. R. N. Chipman, *Chem. Met. Eng.* 35, 49 (1928).
45. Holton, *op. cit.*
46. Ernest Hart, to author, Dec. 4, 1946.
47. Co. memo to author.
48. Shepard, *Chemistry and Toxicology of Insecticides*, p. 111.
49. S. Marcovitch, *Ind. Eng. Chem.* 18, 572 (1926); C. A. Whittle, *Mfrs. Rec.* 92 (Sept. 1, 1927); *Chem. Mkts.* 21, 443 (1927).
50. Shepard, *op. cit.*; Marcovitch and W. W. Stanley, *Ind. Eng. Chem.* 22, 121 (1930); Tenn. Agr. Exp. Sta., *Bull. No. 140* (1929).
51. Tariff Comm., *Report on Sodium Silicofluoride*, 1928, p. 3; *Chem. Mkts.* 20, 811, 984 (1927); 23, 277 (1928).
52. P. Schleussner, *Drug Chem. Mkts.* 12, 1035 (1923).
53. *Ind. Eng. Chem., News Ed.* 5 (Apr. 10, 1923); *Drug Chem. Mkts.* 12, 467 (1923); *Moody's Manual of Investments, Industrials*, 1925, p. 978.
54. *Ind. Eng. Chem.* 16, 267 (1924); Fries, *ibid.* 20, 1080 (1928).
55. D. H. Killeffer, *ibid.* 18, 1043 (1926); *Drug Chem. Mkts.* 18, 371 (1926).
56. L. F. Hoyt and E. P. Ellenberger, *Ind. Eng. Chem.* 19, 461 (1927); Co. memo to author; Minn. Agr. Exp. Sta., *Bull. No. 102* (1926). For bibliography, 1848-1932, see R. C. Roark, Dept. Agr., *Misc. Bull. No. 176* (1934).

57. Weber, *Bureau of Chemistry and Soils*, p. 131.
58. R. T. Cotton and Roark, *Ind. Eng. Chem.* 20, 805 (1928); *ibid.* 21, 79 (1929).
59. *Ibid.* 24, 648 (1932); orig., Cotton and H. D. Young, *Proc. Entomol. Soc.* 31, 97 (1929).
60. J. Warren Kinsman, to author, Jan. 10, 1947.
61. Co. memo to author.
62. *Drug Chem. Mkts.* 14, 1672 (1924); *Drug. Circ.* 71, 446 (1927).
63. L. E. Jackson and H. E. Wassell, *Ind. Eng. Chem.* 19, 1175 (1927).
64. *Chem. Mkts.* 20, 53 (1927); *Ind. Eng. Chem.* 19, 291 (1927). See also M. G. Minaeff, *Textile Colorist* 49, 89 (1927).
65. *O.P.D. Repr.* 19 (July 21, 1924); *Drug Chem. Mkts.* 15, 241 (1924), 17, 149 (1925).
66. *Drug Chem. Mkts.* 17, 224 (1925).
67. *Chem. Mkts.* 19, 1196 (1925); 20, 4 (1927).
68. *Ibid.* 18, 786 (1926).



## Chapter 21

### FROM PLASTICS TO RESINS

SYNTHETIC LACQUERS AND RESINS OPEN NEW OUTLETS FOR COAL-TAR INTERMEDIATES AND SOLVENTS—PHENOLIC PLASTICS MULTIPLY; FURFURAL PLASTICS PRODUCED—DU PONT ACQUIRES CELLOPHANE RIGHTS; CELANESE ABSORBS CELLULOID—CASEIN PLASTICS PERFECTED; ACRYLATE, UREA, STYROL RESINS APPEAR—OIL-SOLUBLE PHENOLIC AND ALKYD RESINS DEVELOPED TO COMPETE WITH NITROCELLULOSE LACQUERS—LACQUER INSTITUTE FORMED.

COMMERCIALIZATION of the synthetic lacquers was the mainspring of the chemical advances which were so characteristic of the 1920's. This new industry opened greatly expanded areas of consumption for coal-tar intermediates and brought to solvents a whole series of novel, precisely specialized uses.\* The sudden demand for products which previously had been inconspicuous or quite unknown was a potent tonic to progress in plants and laboratories. Economically the synthetic resin business soon outgrew its plastics parent. Scientifically its researches in polymers and polymerization led straight to the polymerized fibers and elastomers.

During this decade the plastics industry entered its big-volume phase. The rush of new types of plastics did not come until the 1930's, nevertheless the period was signalized by significant innovations in the old phenolic and cellulosic groups. The enormous demand for phenolic plastics created by the rapid growth of radio, coincided with the expiration of Baekeland's basic patents on the phenol-formaldehyde condensation products, a combination of events that had fourfold results. First, new makers of phenolic plastics sprang up; second, the price, which had been firmly controlled by the Bakelite Corporation, was reduced; third, lower prices created fresh outlets; and finally, the broadening plastics horizons flooded the Patent Office with new types and modifications of phenolic compounds.<sup>1</sup> A particularly notable accomplishment was the oil-soluble phenolic resins, offering the younger lacquer industry an alternate to its nitrocellulose-base materials and producing revolutionary changes in finishes, printing inks, and coated fabrics.

First of the new producers of phenol-formaldehyde condensates was

\* See Chaps. 12 and 13.

the Durez Company. Originally known as General Plastics, Inc., this forehanded enterprise, led by Harry M. Dent, anticipated the expiration of the Bakelite patents in 1927 by incorporating in 1926. Its trade-mark, Durez, was registered as early as November 6, 1923,<sup>2</sup> and its plant at North Tonawanda, New York, was ready for production the moment the patent ban was raised.\* In 1927 the American Catalin Corporation† was incorporated in New York with an active capital of \$133,000, represented by 2,500 shares at \$48 each and 13,000 shares at \$1 each,<sup>3</sup> to produce cast phenolics. In a descriptive announcement,<sup>4</sup> its product was introduced to the industry as "Catalin, an insoluble, infusible cast phenolic resin of gem-like beauty and an unlimited color range, which in forms of rods, tubes, sheets, or shapes can be machined on ordinary shop equipment as easily as wood or brass." This specialization in desirable physical properties and gem-like attractiveness had immediate repercussions. Later that year the Bakelite Corporation announced<sup>5</sup> a new line of resins, "which make possible the reproduction of precious stones," and in 1929 the Kurz-Kasch Company of Dayton, Ohio, bought from Harry N. Copeland his process‡ for producing imitation onyx, agate, and marble from resinoid plastics.<sup>6</sup>

Seeking to avoid interference with phenol-formaldehyde patents, many chemists endeavored to produce plastics from other aldehydes.<sup>7</sup> One of these, based on phenol-furfural, the work of Emil E. Novotny, § came to commercial production. It was fathered financially by a prominent Philadelphia machinery manufacturer, John Stogdell Stokes, long a director of the Pennsylvania Salt Manufacturing Company. These furfural plastics were conducted as a department of Stokes & Smith Company till in 1938 a separate Pennsylvania corporation, Durite Plastics, Inc., was set up, in which the parent firm owned 74 per cent of the stock. They were a factor in helping furfural to become commercially available. This heterocyclic aldehyde ¶ ( $C_4H_3O.CHO$ ) can be

\* Durez' claim to being the first successful, independent competitor of Bakelite is reasonable, for though Condensite (Aylsworth backed by Kirk Brown) and Redmanol, (Redman, Weith, and Brock backed by Karpen) were all on the market long before 1922, nevertheless their patent difficulties with Bakelite were resolved by merger of the three. (See Vol. III, p. 381.) Durite produced phenol-cellulose (sawdust), phenol-starch, and phenol-sugar resins prior to its commercial production of phenol-furfural resins in a small way in 1920 from furfural imported from France and Germany. (E. E. Novotny, to author, Jan. 8, 1947.) Strictly speaking, none of these plastics were direct competitors of the phenol-formaldehyde products.

† Name later changed to Catalin Corp.

‡ U. S. Pat. 1,735,674 (1929).

§ Since the founding of Durite Plastics, 1920, Novotny has been its mgr. and research dir. He holds over 200 patents on synthetic resins, especially the furfural type.

¶ First observed by Doebereiner as a by-product in the preparation of formic acid by the action of  $H_2SO_4$  and  $MnO_2$  on sugar, and obtained by G. Fownes (1845) by

quite simply prepared by hydrolysis of the pentosans occurring naturally in oat, rice, and cottonseed hulls, corncobs, bran, and even kapok.<sup>8</sup> During World War I, interest was aroused in possible syntheses on the basis of the furan radical, and the chemists of the Department of Agriculture worked out tentative processes for furfural from a number of agricultural wastes. The economic problem of collecting sufficient farm-waste raw material checked development \* until the Quaker Oats Company, with a large, available waste of oat hulls at the Cedar Rapids, Iowa, plant, turned the problem over to Carl S. Miner,† director of the Miner Laboratories in Chicago. Aided by the excellent data on furfural-water mixtures collected by G. H. Mains<sup>9</sup> at the Bureau of Chemistry, Miner and H. J. Brownlee not only worked out a commercially practical process, but continued elaborate researches developing uses.<sup>10</sup> Furfural did not come quickly into its own as a chemical reagent. Novotny's use of it in plastics‡ was the first considerable commercial application and the first quantity market was in the purification of wood rosin, carload shipments being made to Hercules before furfural's use as a selective solvent for petroleum lubricants.<sup>11</sup> The first drum of furfural produced in 1922 sold for \$1 per pound, but with the expanding market declined to 10 cents per pound in 1929.

After several years of rough sailing through financial shoals, the first of all American plastics companies, Hyatt's original Celluloid Manufacturing Company, came on the rocks in 1927. The rapid rise of the phenolic plastics, faulty business judgment, the aggressive competition from younger American manufacturers of nitrocellulose plastics and from cheap pyroxylin goods from Japan, all contributed to these difficulties which were finally resolved by joining forces with the Celanese Corporation. § There was chemical common sense behind this merger. Camille and Henry Dreyfus readily recognized the chemical and com-

distilling brar. with  $\text{H}_2\text{SO}_4$ . For early history, see J. W. Doebereiner, *Ann.* 3, 141 (1832); A. Cahours, *ibid.* 69, 82 (1849); L. V. Babo, *ibid.* 85, 100 (1853).

\* "Although it was well known that furfural could be obtained by the hydrolysis of almost any plant material, there was no incentive to produce it because there were no markets. The same situation exists today in the case of xylose which can be obtained from plant materials by partial hydrolysis. Thus it happened that the commercial production of furfural arose, not because of a desire to produce this aldehyde, but because it was obtained in a 10% yield as a by-product in an attempt to improve the value of oat hulls as a cattle feed. Two hundred pounds per ton was too much material to throw down the sewer, so a search for furfural markets began and has continued till this day." (L. B. Hitchcock, to author, Jan. 23, 1947.)

† A leading chem. consultant of the Middle West, Miner was born in Iowa, 1878, and graduated from U. Chicago with a B.S. in 1903. Save for 3 yrs. as chem. with Corn Products, he has headed his own labs. since 1906. He has been chmn. of the Chicago Sect. and councilor of the Am. Chem. Soc.

‡ For Novotny's own account of these early developments, see Appendix XLIV.

§ Originally the American Cellulose & Chemical Manufacturing Co., Ltd. See Vol. III, p. 376.

mercial bonds uniting cellulose acetate and cellulose nitrate products. The Tennessee Eastman Corporation, which had been organized in 1920, was manufacturing acetate film and had put on the market in the form of rods, sheets, and tubes an acetate plastic trade-named Tenite. Attention of the Dreyfus brothers was thus sharply focused on the field of both film and plastics. In fact, in 1925 they had secured the rights to the process\* of manufacturing phenol-aldehyde condensation products in the presence of stannous chloride.<sup>12</sup> This was a discovery of George W. Miles of Boston, previously associated with Arthur D. Little, who had been the first to make cellulose acetate from the unaltered fiber by means of a catalyst, as well as the hydrated acetate soluble in acetone. The Celluloid Manufacturing Company not only offered the Dreyfus brothers a springboard into the plastics field, but it had itself made considerable, though not profitable, contributions to both acetate and lacquer, being a pioneer in the development of tricresyl phosphate as a camphor substitute and through the researches of William G. Lindsay holding some interesting patents on acetate solvents and motion picture films.<sup>13</sup> Nitrocellulose molding powder had come on the market in 1926 and one of the first fruits of this consolidation was acetate molding powder, introduced under the trade name of Lumarith in 1929.<sup>14</sup>

Omitting the spectacular arrival of lacquers, the most significant innovation in the cellulose field during these years was the development of the transparent wrapping film. In 1923 the du Pont Company bought American patent rights to a transparent cellulose (viscose) sheeting from La Cellophane by giving the French interests a substantial stock interest in a new subsidiary, the du Pont Cellophane Company. Cellophane had its origin in the experiments of a French textile chemist, J. E. Brandenberger, who in the early years of the century experimented with coating cotton tablecloths with a nitrocellulose lacquer to render them impervious to stains and easily cleanable. His initial efforts were discouraging. The impregnated cloth was stiff and brittle. So he tried attaching a thin sheet of viscose material to the fabric. This coated cotton cloth was thick and inflexible, but he was now on the trail of the idea of a thin, transparent, cellulose sheeting, and persevering, he was able by 1912 to reduce its thickness and brittleness to approximately the present properties of Cellophane. The largest European manufacturers of viscose rayon, the Comptoir des Textiles Artificiels, became interested, backed his idea financially, and La Cellophane Company grew up based on the Brandenberger process. Du Pont built a plant at Buffalo and in the spring of 1924 the first American-made Cellophane appeared on the market at \$2.65 a pound.<sup>15</sup> From here on in the story

\* U. S. Pat. 1,549,888 (1925).

is one of ingenious research to improve the properties of the product and of farsighted price reductions to broaden the market.

At its introductory price, Cellophane was coolly welcomed as a hat trimming by the millinery trade. It was too expensive for its destined use as a wrapping sheet and besides it had the handicap of not being moistureproof. Cordially supported by the du Pont management, the executives of the Cellophane subsidiary, led by Leonard A. Yerkes and B. M. May,\* adopted a double campaign attacking these weak points. Within two years the price was cut to \$1.65 a pound.<sup>16</sup> Whitman's chocolates were the first big victory in a sales campaign in the wrapping field, followed by the capitulation of manufacturers of cookies, candy bars, and bacon. In 1927 it was triumphantly announced that golf balls were to be wrapped in Cellophane.<sup>17</sup>

Two years earlier Dr. William Hale Charch† started a research to render Cellophane moistureproof. After many experiments, in which a team of du Pont research chemists and engineers participated, he and Karl E. Prindle‡ developed a waxy modification of Duco lacquer which proved a suitable moistureproofing coating. § In 1929 the du Pont Cellophane Company announced plans for an additional plant at Old Hickory, Tennessee.<sup>18</sup> By this time the price was 70 cents a pound, less than a third of that but five years' previous.

That same year the du Pont Cellophane Company bought Capes-Viscose, Inc., makers of Cel-O-Seal bottlecapping caps and bands.<sup>19</sup> In

\* Yerkes was pres.; May, vice-pres. and treas.; M. du Pont Lee, secy.; and J. S. Denham, sales mgr. Dir. were Wm. C. Spruance, Jr., chmn., Yerkes and May, Albert Blum, H. L. Blum, Lamont du Pont, Charles Gillet, B. C. Paskus, F. W. Pickard, and Fin Sparre. With the two active executives, Spruance had been closely associated in du Pont rayon activities, which had also involved the purchase of American rights to the French company's patents. See also Vol. III, p. 375.

† Since 1936 Charch had been dir. of du Pont's Pioneering Research Sect. of the Rayon Dept. He was born in Dayton, O., Mar. 20, 1898, and earned his A.B. at Miami U., M.S. and Ph.D. at Ohio State (1920-23). After 2 yrs. with General Motors Research Corp., he came to du Pont in 1925. In 1932 he was awarded the Schoellkopf gold medal of the Western N. Y. Sect., Am. Chem. Soc.

‡ U. S. Pat. 1,737,187 (1929). Prindle later left du Pont and went with the Dobeckmun Co., in Cleveland, which processes Cellophane.

§ "It is true that we made a very large number of lacquer formulations before a completely suitable moistureproof coating was developed. I hardly like to look on these as separate experiments. We were the first to successfully combine the high moistureproofing properties of paraffin with a nitrocellulose lacquer material. Prior to that time paraffin had been considered incompatible with cellulose lacquers and caused blush, slow drying of solvents, etc. It was necessary for us to find lacquer compositions which would tolerate paraffin and which could be dried under special conditions to give perfectly transparent, moistureproof coatings equal to the best waxed papers of the day. If the nitrocellulose lacquer industry had not been in existence we would not have been able to solve our problem at that time. Actually, the moistureproofing of Cellophane was, technically speaking, a broadening out or extension of Duco lacquers to include an ingredient (paraffin) which would render them highly resistant to the passage of moisture." (W. H. Charch, to author, Mar. 5, 1947.)

the autumn of the next year it announced the building of a larger, \$4,000,000 plant at Amphill, near Richmond, Virginia; the doubling of the new plant at Old Hickory; and a further price reduction.<sup>20</sup> At this time it was noted that the price of Cellophane had been reduced twelve times since domestic production began.<sup>21</sup> Du Pont's keen interest in pyroxylin products was also evidenced by purchasing the Viscoloid Company, organizing the du Pont Viscoloid Company in 1925 and the next year, in cooperation with the United Shoe Machinery Company, introducing Celastic, a pyroxylin-impregnated fabric for use in the shoe industry.<sup>22</sup>

The success of Cellophane attracted competition. In 1929 the Sylvania Industrial Corporation was formed with \$3,500,000 capital to manufacture a viscose sheeting in a new million-dollar plant in Fredericksburg, Virginia.<sup>23</sup> This new enterprise was headed by Roger N. Wallach,\* formerly vice-president of Grasselli Dyestuff Corporation, who was president, and Frank H. Reichel, who was the active general manager. Beside Sylvania's Sylphrap, within two years the Eastman Kodak Company was to be on the market with an acetate sheeting, Kodapak. Competition from abroad in transparent wrappings was thrashed out in the tariff hearings of 1929, when Birn & Wachenheim of New York City filed a brief<sup>24</sup> protesting against a higher duty than 25 per cent. Prior to 1925 this firm had been importing transparent sheeting under the trade name of Fenestra, manufactured in Germany.

Akin to transparent sheetings was the development of the viscose sausage casing, whose manufacture was first undertaken in this country in 1926 by the Visking Corporation.<sup>25</sup> But all these interesting developments were overshadowed by the phenomenal growth of lacquers which in 1922 consumed<sup>26</sup> 1,000,000 pounds of cellulose and in 1929 over 20,000,000 pounds.† At this time the chief producers of pyroxylin compounds were, beside du Pont and Kodak, the Hercules Powder Company with its plant at Parlin, New Jersey, and its interest in the Virginia Cellulose Company at Hopewell, Virginia, and the Atlas Powder Company which had acquired the Zapon line of pyroxylin coatings at Stamford, Connecticut. In Newark, New Jersey, a real pioneer, Charles Cooper & Company, extended greatly its line of Keratol products, pyroxylin-coated fabrics sold as "artificial leather," and the Franco-American Chemical Works near by was also a large producer of specialty pyroxylin compounds. Up in New England the Merrimac Chemical Company, which had absorbed Anderson and was

\* Prior to founding Sylvania, Wallach (1882-1941) had also been pres. and dir. of Filatex Corp.

† In the sensational growth of the lacquers, it should not be overlooked that in 1922 the first nail enamels appeared, a business that during the 1930's reached tankcar shipments of pyroxylin solutions to toilet-goods manufacturers.

itself to join Monsanto in 1929, was the principal producer of pyroxylin solutions, while among the manufacturers of paints, Sherwin-Williams was one of the first to enter the nitrocellulose field.<sup>27</sup>

Diversification of plastic materials, the salient development of the next decade, started during the 1920's. Casein plastics established themselves more firmly, and to Peter C. Christensen's pioneering Aladdinite were added Karolith, Kyloid, and Inda.<sup>28</sup> The distinctive use of this plastic in buttons developed early, and in 1928 George Morrell purchased the struggling Kyloid plant and joined it directly to his button factory. A year later Christensen discovered \* that the addition of a small amount of alum hardened a casein plastic sufficiently so that it could be worked in machines, and about 1931 he organized the Button Corporation of America and discontinued the manufacture of Aladdinite.<sup>29</sup> Karolith, the first commercially successful American casein plastic, was perfected after five years' research at the Mellon Institute and produced first in 1924 by the Karolith Corporation of Long Island City.<sup>30</sup> In Britain during World War I, a process from rennet casein had been worked out and postwar the Erinoid Company of England was founded to develop this material.<sup>31</sup> In 1925 the Erinoid Company of America was organized with the backing of the Casein Company of America<sup>32</sup> to transplant the process to this country.

Promises of the diversification of the 1930's were the appearance in 1927 of an acrylate resin, introduced as Plexigum by the Resinous Products & Chemical Company, a subsidiary of Rohm & Haas,<sup>33</sup> and the announcements in 1929 that two urea-formaldehyde plastics, Beetle and Aldur, were in commercial production, and that styrol resins were out of the laboratory and ready for commercial exploitation.<sup>34</sup> During the late twenties two companies were organized to invade the byways of the plastics field. The Kelp Products Company proposed to manufacture plastics from marine algae according to the patent † of C. C. Loomis and A. L. Kennedy,<sup>35</sup> while the American Nuplax Corporation bought the American rights ‡ to the process of Felix Homberg and Max Landecker of Barmen, Germany, for the fabrication of colored plastics from blood.<sup>36</sup>

In the field of synthetic resins, the 1920's witnessed two tangible commercial triumphs, oil-soluble phenolics and the alkyds. Thus Leo Baekeland's dream of a cheap, synthetic varnish gum was belatedly fulfilled and the coatings industry, jolted out of old ruts by nitrocellulose plastics, was revolutionized by the arrival of these synthetic resins.<sup>37</sup>

\* U. S. Pat. 2,097,144 (1937).

† U. S. Pat. 1,603,783 (1926).

‡ U. S. Pat. 1,724,088 (1929).

An early substitute for the excellent but expensive copal, dammar, and other natural resins was the chemical modification of rosin to render it harder and more waterproof and to remove its tendency to crack and bloom when used in varnish formulations. These disadvantages arise from high acidity, and one of the earliest improvements was treatment with lime.\* Neutralization by means of other metallic oxides—zinc, barium, lead, and manganese—followed and soon led to a cheap varnish made from hardened rosin and solvent naphtha, known to the trade as “gloss oil.” The next step was the preparation of rosin esters† formed by the combination of rosin with 10–15 per cent glycerin, known as “ester gum.” These products had improved qualities of hardness and durability, freedom from bloom, and from “livering” with basic pigments.<sup>38</sup>

These treatments of rosin increased its consumption in a number of different industries, and its production during this period underwent great change due to the development of the wood rosin industry.<sup>39</sup> Contradicting the positive prediction of the Department of Agriculture that somewhere between 1925 and 1930 American naval stores would vanish due to the destruction of the Southern pine forests,<sup>40</sup> output of both rosin and turpentine far exceeded demand in 1927 and 1928. Prices slumped and to save the situation, July 1928, the Naval Stores Marketing Corporation was organized in an effort to centralize and stabilize the disorganized sales mechanism of this scattered industry of small-unit producers.<sup>41</sup> Simultaneously the export market, which at this time normally absorbed over half our rosin and some 40 per cent of our turpentine, was gravely curtailed so that the Naval Stores Export Corporation,<sup>42</sup> organized in 1923 under the Webb-Pomerene Act, was disbanded in 1928, its business being taken over by Gillican-Chipley Company of New Orleans.<sup>43</sup>

Recognizing the plight of the turpentine farmer, government aid was suggested by including naval stores in the McNary-Haugen bill for cooperative marketing. This move was protested by consumers, notably the American Paper & Pulp Association, whose secretary, Dr. Hugh P. Baker, appeared at the Congressional hearings.<sup>44</sup> The inclusion of naval stores in this agricultural relief measure and the close cooperative work on standards and better methods of cultivation with the Bureau of Chemistry and Soils ‡ established a precedence of federal relief, which during

\* Lime-hardened rosin was first proposed in 1884 by A. Kissel: U. S. Pat. 303,436, ass. to C. Zimmer; reissue 10,714 (1886); U. S. Pat. 441,366 (1890). Kissel also suggested other bases, baryta and magnesia. Zinc and other metallic oxides were first advocated by J. B. Melvin in U. S. Pat. 370,640 (1887).

† The first ester gum was prepared by E. Schaal: U. S. Pats. 335,485 (1886), reissue 10,823 (1887), 368,494 (1887), 501,446 (1893).

‡ In 1929 a Naval Stores Advisory Comm. to confer with the Bur. was named as



the Great Depression was to bring mixed blessings to this oldest of American industries.

The lively survival of naval stores production and the collapse of naval stores prices completely upset the calculations upon which the two strong chemical companies, Newport and Hercules, had embarked seriously in the production of wood rosin.\* But both persevered, and working independently, cut costs and improved their products, producing a light-colored rosin and an odor-free turpentine. They also replaced the old wooden barrel with steel drums and modernized their marketing systems. Such tangible progress was made that by the end of the decade, E. C. Meriwether, president of the American Turpentine & Tar Company, in his annual review in *Gamble's Yearbook*,<sup>45</sup> admitted that prejudice against wood rosin and steam-distilled turpentine had virtually disappeared and that contrary to the market, demand for this turpentine and for pine oil already exceeded supply. Uncovering markets for pine oil was one of the real tasks of this period. Both companies contacted all potential consumers and research fellowships at various colleges supported by Hercules provided a number of promising leads.<sup>46</sup> While the largest consumption of pine oil grew in flotation oils and disinfectants, diversified uses were developed in textile chemicals, detergents, insecticides, and aromatics.

Evidence that the wood rosin business had found itself came in 1927 when the Newport plant at Pensacola was doubled at a cost of \$400,000,<sup>47</sup> followed the next year by the purchase of the Acme Products Company, in De Quincy, Louisiana.<sup>48</sup> This plant had been built in 1922, employing the steam and solvent process, and was the home of a process developed under the W. B. Logan patent,<sup>†</sup> producing an FF grade of rosin with exceptional noncrystallizing properties, known as Solros.<sup>49</sup> A number of companies in this field dropped out during this period,<sup>50</sup> but one new firm that survived, the Dixie Pine Products Corporation, began operations with the steam and solvent process in 1928 at Hattiesburg, Mississippi.<sup>51</sup> The young wood-rosin industry was not without its own competitive difficulties and in 1929 it followed the fashion of the day and in consultation with the Federal Trade Commission,<sup>52</sup> adopted a code of business ethics. ‡

follows: J. B. Davis, J. B. Davis & Co., Albany, Ga.; F. L. Fogarty, Wood Chemical Products Co., Jacksonville; H. L. Kayton, Carson Naval Stores Co., Savannah; J. E. Lockwood, Hercules Powder Co.; C. L. Morrison, Morrison Co., Olustee, Fla.; J. C. Nash, Columbia Naval Stores Co., Savannah; R. M. Newton, Newton Naval Stores Co., Wiggins, Miss.; C. F. Speh, secy.-mgr., Pine Inst.; T. J. Taylor, Taylor, Lowenstein & Co., Mobile; and H. M. Wilson, Baldwin-Lewis-Pace Co., Jacksonville. [See *Chem. Mkts.* 25, 67 (1929).]

\* See Vol. II, Chap. 21.

† U. S. Pat. 1,643,276 (1927).

‡ Representatives of the industry at this code conference were: F. W. Kressman and

While rosin was being modified chemically to meet the requirements of the varnish manufacturers, phenolic resins were also beginning to be experimented with to make them soluble in drying oils and hence also available to the coatings industry. The earliest method was fusion with rosin, but soon better results were obtained from modified rosins such as ester gums and coumarone.<sup>53</sup> The first American patent for this type of synthetic, oil-soluble resin was taken out as early as 1917\* by A. L. Brown and assigned to the Westinghouse Electric & Manufacturing Company. Another approach was through the modification by drying oils, tung oil being the favorite. An early proprietary oil-soluble resin was Amberol, introduced in the middle 1920's and followed by Ambertol, by the Resinous Products & Chemical Company, which was formed in 1926, with Otto Haas, president of the associated Rohm & Haas Company, as president, and E. C. B. Kirsopp as vice-president. The company had acquired patent rights to the oil-soluble Ambertols,† which are produced by reacting phenols with rosin. The first so-called "4-hour enamels" were made with the Amberols by such paint and varnish companies as George D. Weatherill, Pratt & Lambert, and Murphy Varnish. From this beginning they found their way into other uses in the coatings field, such as spar varnish, baking and air-drying varnishes and enamels, and lacquers. It was a short step to related uses in printing inks, floor coverings, and oilcloth.<sup>54</sup>

By the middle 1920's these various modified phenol-aldehyde resins were sufficiently standardized to warrant commercial attention. They were welcomed by the varnish makers who were being hard pressed by the tough, quick-drying nitrocellulose lacquers. Although these resins did have some specific useful characteristics besides quick-drying—they were used with notable success in antifouling ship-bottom paint<sup>55</sup>—they had their definite limitations and were by no means a complete answer to the threat of lacquers. Loss of the rich automobile market was incentive enough to find that answer. It was found in new types of synthetic resins that were not modifications either of natural gums or of phenol-aldehyde plastics.

A multitude of such oil-soluble synthetic resins began to appear. Some of the earliest were condensation products of aldehydes and such phenolic substances as *o*- and *p*-cresols, xylene, and toluene, or of reacting phenol with *p*-nitroaniline, various ketones,  $\beta$ -naphthol, and

W. H. Crawford, Continental Turpentine & Rosin Corp.; T. F. Dreyfus and S. Lowenstein, Dixie Pine Products; L. N. Bent, Jesse Gibson, J. C. Haile, and J. E. Lockwood, Hercules; and S. J. Spitz, J. H. McCormack, and E. E. Holdman, Newport.

\* U. S. Pat. 1,212,738.

† U. S. Pats. 1,614,171, 1,623,901 (1927), 1,658,828 (1928), and 1,736,757 (1929), granted to A. Amann and E. Fonrobert, ass. to Chemische Fabriken Dr. Kurt Albert G.m.b.H.

other reagents.\* These resins were quick-drying and several had other distinctive, useful properties. However, none was sufficiently cheap or effective to replace the natural varnish gums or to become a real competitor of nitrocellulose lacquer. This double achievement came from an entirely different group, the alkyd resins, reaction products of polyhydric alcohols (glycerin, ethylene glycol, and their homologs) and polybasic acids (phthalic, tartaric, citric, succinic, and others).

Resins of this type had long been known, but the early investigators were interested solely in the chemical reactions involved.† In 1901 the English chemist Watson Smith, while endeavoring to make a phthalein dye, produced from glycerin and phthalic anhydride a clear resin which he studied<sup>56</sup> and recommended as a cement for glass and earthenware. In this country, even before World War I, phthalic glyceride as a possible resin attracted the attention of Condensite and General Electric.‡ In the Schenectady laboratory of the latter firm, Michael J. Callahan left the first record§ of experimentation in the alkyd resins, and he and his coworkers developed quite a series of likely materials within this group. After the war the rocket-like rise of lacquers and superior types of quick-drying varnishes, together with the availability of cheap phthalic anhydride and a variety of new solvents, revived interest in the alkyd resins.<sup>57</sup> Out of General Electric's persistent, patient work came eventually its line of alkyd resins known as Glyptals, which were commercially introduced in 1929, at which time also Resinous Products brought out another type of alkyd resin, known as Paraplex, prepared from sebacic acid rather than phthalic anhydride. To make this product commercially feasible the Resinous Products & Chemical Company had to devise a process for the manufacture of sebacic acid, formerly a chemical curiosity at \$10 or more a pound which now became available at approximately 50 cents a pound.<sup>58</sup>

Pyroxylin solutions and synthetic resins between them created undreamed-of opportunities for protective and decorative finishes and upset many preconceived ideas. They stirred the old paint and varnish industry to the core and created a new chemical industry to supply the base materials, plasticizers, and solvents for the new products.

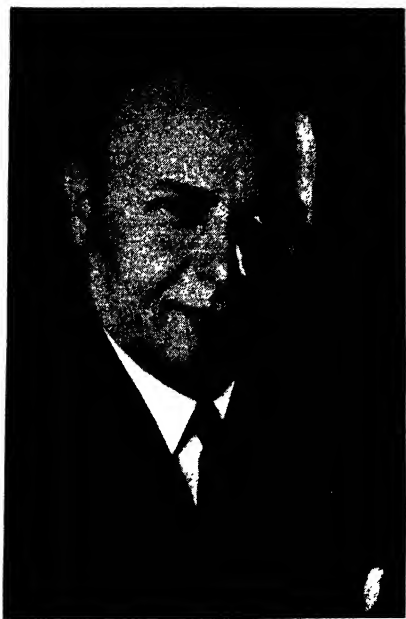
In pyroxylin lacquers the du Pont Company was undoubtedly the chief trail breaker. The excellence of its product, Duco, introduced in 1923,<sup>59</sup> and the close connection with General Motors, were impor-

\* For details and patent references, see Ellis, *Chemistry of Synthetic Resins*, p. 407.

† Early in the last century Berzelius reported a resin from glycerin and tartaric acid, and in 1856 van Bemmelen prepared resins by heating glycerin with succinic, benzoic, or citric plus succinic acids (*J. prakt. Chem.* 69, 84). For review of these early researches, see R. H. Kienle and C. S. Ferguson, *Ind. Eng. Chem.* 21, 349 (1929).

‡ See Vol. III, p. 221*n*.

§ U. S. Pats. 1,108,329-32 (1914), ass. to General Electric Co.



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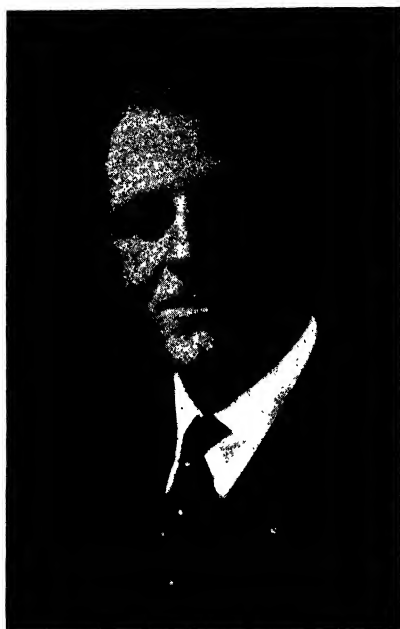


JAMES A. SINGMASTER



*Oil, Paint & Drug Reporter*

**JOHN B. GORDON**

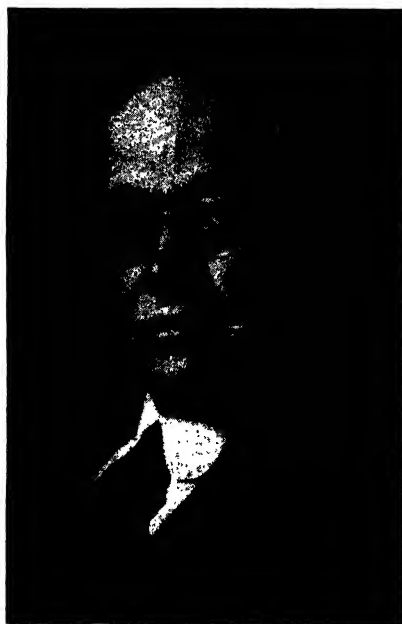


**B. F. WILLIAMSON**



*Oil, Paint & Drug Reporter*

**HENRY A. GARDNER**



**C. K. WILLIAMS**

tant elements in the swift conquest of lacquers in the automobile field. Within three years every motor car manufacturer, except Ford, had gone over to the new finish. In 1927 even Ford forsook varnish for a special oil-soluble resin lacquer developed by the Glidden Company for which Ford placed an exclusive contract reported<sup>60</sup> at the time to aggregate over \$1,500,000 a year. The year before this du Pont introduced its Duco brush lacquer and in 1928 obtained the Flaherty patent on low-viscosity lacquers, which brought on licenses and lawsuits in the next decade.

But du Pont was not alone in this pioneering work. The Hercules Powder Company also developed a low-viscosity nitrocellulose lacquer base which it sold to the coatings industry. It had bought the Virginia Cellulose Company plant at Hopewell shortly after the war and from here supplied nitrocellulose to the Union plant at Parlin, New Jersey, where the material was converted into the clear base product for lacquer manufacturers.<sup>61</sup> In 1928 the Hopewell unit was provided with a new power plant and on July 1, 1929, the Virginia Cellulose Company was absorbed by Hercules. That same year the American Cyanamid Company, by purchase of the American Powder Company,\* entered the field of nitrocellulose manufacture.<sup>62</sup> One of the oldest explosives companies in the country, with a plant at Maynard, Massachusetts, American Powder had largely dropped the manufacture of powder and turned to the production of pyroxylin base and solution.

Important new companies also entered this field. In 1925 Rohm & Haas began the manufacture of nitrocellulose leather finishes and the following year its subsidiary, the Resinous Products & Chemical Company was incorporated in Delaware for \$1,000,000 to manufacture oil-soluble resins.<sup>63</sup> At the same time it increased its own capital from \$1,000,000 to \$5,000,000.<sup>64</sup> Another company destined to play a prominent role in synthetic resins, Reichhold Chemicals, Inc., was organized in 1925 by Henry H. Reichhold and in 1927 completed its first manufacturing plant at Ferndale, near Detroit.<sup>65</sup> Two years later Reichhold bought out Synthe-Copal Company, ester gum producers of Buffalo.

In 1925 the Van Schaack Brothers Chemical Works of Chicago, which manufactured a varied line of lacquer chemicals, made a \$500,000 addition to its plant,<sup>66</sup> and the next year the Pyroxylin Products Company was organized in Chicago to manufacture cellulose derivatives.<sup>67</sup> The general manager of the new concern was Charles E. Fawkes, while production and research was in charge of Dr. W. Courtney Wilson.†

\* At the time of the sale, its officers were M. J. Connolly, pres.; T. M. R. Meikleham, vice-pres. and treas.; and E. W. Hawley, vice-pres.

† Wilson, who was with Atlas Powder, 1918, and Miner Labs., 1924-25, made early significant contributions to low-viscosity nitrocellulose. He was born 1894 in New

In 1927 William Harrison and Harry W. Meyerson organized the Bayway Industrial Chemical Company in New Jersey and built a plant at Elizabeth to manufacture lacquer products and by-products.<sup>68</sup>

That year the first company to make lacquer bases on the Pacific Coast, Lacquer Chemicals, Inc., was incorporated with a capitalization of \$300,000, backed jointly by the Stauffer Chemical Company and Western Industries. The directors were Leon Bocqueraz, president of the French-American Bank; Roger Bocqueraz general manager of the American Solvents & Chemical Corporation; John Stauffer, Jr.; and Hans Stauffer.<sup>69</sup> A \$200,000 plant was built near Richmond, California, on ten acres of land owned by Stauffer, an operation that included a nitrating unit working on California cotton linters. Also on the West Coast, at Los Angeles, the Brown-Leithold Company was reported to have a production of 2,000 gallons of lacquer daily in 1927.<sup>70</sup>

Since before the Pharaohs, paints had been made by grinding colors in oil, varnish by boiling natural gums, and to this ancient craft the sudden appearance of synthetics was as strange and unexpected as a man from Mars in a Broadway night club. But the coatings manufacturers recovered their equilibrium quickly. They purchased the unaccustomed raw materials and began turning out lacquers. Large and small firms entered the new field and more than this, they entered it with spirit and determination.\* Their decision may have savored somewhat of Hobson's choice, nevertheless many companies, forsaking their traditional rule-of-thumb practices, took to research. This was one of the most brilliant and complete feats of chemical modernization ever accomplished by an age-old industry. The change in mental attitude led naturally to many changes in company organizations and in personnel. For example, two of the oldest firms, the Standard Varnish Works and Toch Brothers combined in 1926,<sup>71</sup> and in 1927 the well-established Hilo Varnish Corporation, of which John H. Schumann was president, increased its capital from \$600,000 to \$1,000,000 to expand by manufacturing pyroxylin lacquers.<sup>72</sup>

How completely the coatings industry had adopted lacquers is shown in the officers elected by the newly formed Lacquer Institute in 1929. This had been organized by 17 different companies with a combined output of approximately 75 per cent of the domestic production. The

Wilmington, Pa., and graduated from Westminster Coll., B.S., 1917; U. Ill., M.S., 1920, Ph.D., 1922.

\* It is interesting to speculate what the course of the modern coatings industry would have been if Hercules, Atlas, Tennessee Eastman, Cooper, and the other manufacturers of nitrocellulose-base materials had adopted the policy of du Pont and made and marketed pyroxylin lacquers under their own brands. Today lacquers, plastics, and rayon all show the reluctance of the chemical manufacturing companies to enter the strange arena of consumer goods. (W. H.)

chairman was Charles H. Reed of Forbes Varnish Company; the vice-chairman, A. W. Steudel of Sherwin-Williams; the secretary-treasurer, H. B. Sweatt of New York. These officers, with W. C. Dabney of Jones-Dabney and P. E. Kennedy of the Murphy Varnish Company, comprised the executive committee.<sup>73</sup> The first topic to be discussed by the Institute was a uniform cost-accounting system.<sup>74</sup>

## REFERENCES

1. *Plastics* 6, 396 (1930); *Tariff Comm., Synthetic Resins and Their Raw Materials*, Ser. 2, Rept. No. 131, p. 12. See also E. F. Lougee, *Dun's Rev.* 22 (Dec. 1939).
2. Co. prospectus, Apr. 15, 1938, p. 21; *Mod. Plastics* 26 (Nov. 1934).
3. *Chem. Mkts.* 20, 412 (1927).
4. Quoted in adv., *Plastics Catalog*, 1944, p. 245.
5. *Chem. Mkts.* 21, 749 (1927).
6. *Plastics* 6, 332 (1930); see also DuBois, *Plastics*, p. 113.
7. Ellis, *Chemistry of Synthetic Resins*, Chaps. 18 & 24.
8. F. B. LaForge, *Ind. Eng. Chem.* 15, 499 (1923); D. H. Killeffer, *ibid.* 18, 1217 (1926); F. N. Peters, Jr., *ibid.*, *News Ed.* 15, 269 (1937); F. Hardy, *Trop. Agr.* 1, 158 (1924); *Chem. Trade J.* 78, 407 (1926); A. J. Hammer, *J. Soc. Chem. Ind.* 52, 608 (1933).
9. *Chem. Met. Eng.* 26, 779 (1922); 31, 307 (1924).
10. C. S. Miner, J. P. Trickey, and H. J. Brownlee, *ibid.* 27, 299, 362 (1922); C. Marx, *Plastics* 6, 202 (1930).
11. Peters, *Ind. Eng. Chem.* 28, 755 (1936).
12. *Plastics* 1, 26 (1925).
13. *Chem. Met. Eng.* 34, 468 (1927); J. Rossman, *Plastics* 6, 22 (1930); *Fortune* 144 (Oct. 1933).
14. *Plastics* 6, 104 (1930).
15. Co. memo to author; *Fortune* 74 (Feb. 1932); *Chem. Met. Eng.* 29, 594 (1923); *O.P.D. Repr.* 18 (Sept. 24, 1923); *Ind. Eng. Chem.* 15, 1041 (1923).
16. H. J. Skinner, *Ind. Eng. Chem.* 24, 703 (1932).
17. *Chem. Mkts.* 21, 138 (1927).
18. Skinner, *op. cit.*; *Rayon* 33 (Mar. 15, 1929).
19. Co. memo to author; *Chem. Mkts.* 24, 72 (1929).
20. *Chem. Mkts.* 27, 509 (1930); *O.P.D. Repr.* 31 (May 5, 1930).
21. *O.P.D. Repr.* 64 (Oct. 6, 1930).
22. *Ibid.* 97 (Apr. 20, 1925); *Ind. Eng. Chem.* 17, 472 (1925); *Drug Chem. Mkts.* 16, 1035 (1925); *Plastics* 6, 180 (1930).
23. *Chem. Mkts.* 24, 629 (1929); L. B. Hitchcock, *ibid.* 26, 366, 513 (1930).
24. Hearings Finance Comm. (S. 71:1) on *Tariff Act of 1929* (H.R. 2667), Sched. 1, June 1929, p. 169; *O.P.D. Repr.* 43 (June 24, 1929).
25. W. F. Henderson and H. E. Dietrich, *Ind. Eng. Chem.* 18, 1190 (1926).
26. D. R. Wiggam and W. E. Gloor, *Ind. Eng. Chem.* 26, 551 (1934).
27. *Chem. Met. Eng.* 37, 16 (1930).
28. G. H. Brother, *Ind. Eng. Chem.* 32, 31 (1940).
29. *Mod. Plastics* 28 (Oct. 1939).
30. Brother, *Plastics* 2, 13 (1926).
31. *Ind. Chemist* 9, 193 (1933); R. Dodd, *Trans. Inst. Plastics Ind. (London)* 5, No. 10, 58 (1936).
32. *Ind. Eng. Chem., News Ed.* 5 (Jan. 10, 1925).
33. *Tariff Comm., Synthetic Resins, op. cit.* p. 36.
34. *Chem. Met. Eng.* 37, 47 (1930); *Chem. Mkts.* 24, 409 (1929); *Plastics* 6, 104 (1930).
35. M. Deschiens, *Plastics* 6, 657 (1930).
36. *Ibid.* 140; O. Wilson, *Ind. Eng. Chem.* 18, 703 (1926); C. L. Gabriel and F. M. Crawford, *ibid.* 22, 1163 (1930).
37. E. C. Holton, *Am. Paint & Varnish Mfrs. Assoc., Sci. Sect., Circ. No.* 404, 653 (1931) & *Chem. Mkts.* 30, 40 (1932).
38. C. Ellis and L. Rabinovitz, *Ind. Eng. Chem.* 8, 406 (1916); A. C. Johnston, *ibid.* 21, 688 (1929); A. Murray, *Chem. Met. Eng.* 25, 473 (1921); Ellis, *Chemistry of Synthetic Resins*, p. 773.
39. For review of these developments, see



- E. V. Romaine, *Chem. Ind.* 45, 402 (1939); Haynes, *Southern Horizons*, Chap. 7.
40. *Gamble's Naval Stores Yearbook*, 1926, p. 2.
41. *Chem. Mkts.* 29, 142 (1931).
42. O.P.D. *Reptr.* 39 (Feb. 17, 1919); *Drug Chem. Mkts.* 13 (Feb. 12, 1919); *Ind. Eng. Chem.* 11, 381 (1919).
43. *Chem. Met. Eng.* 35, 770 (1928).
44. *Drug. Chem. Mkts.* 18, 701 (1926); O.P.D. *Reptr.* 33 (Mar. 15, 1926).
45. *Gamble's Naval Stores Yearbook*, 1927-28, p. 67.
46. J. L. Schantz and T. Marvin, *Ind. Eng. Chem.* 31, 595 (1939); *Gamble's Naval Stores Yearbook*, 1928-29, p. 89.
47. *Chem. Mkts.* 20, 304 (1927).
48. R. C. Palmer, *Ind. Eng. Chem.* 27, 741 (1935).
49. *Gamble's Naval Stores Yearbook*, 1931-32, p. 88.
50. *Ibid.*, 1927-28, p. 70.
51. Palmer, *op. cit.*
52. *Chem. Mkts.* 25, 69 (1929).
53. For reviews of early oil-soluble resins, see E. Fonrobert and Marx, *Chem. Age (N. Y.)* 32, 167, 221 (1924); *Paint, Oil & Chem. Rev.* 88, No. 17, 89 (1929); H. M. Johnson, *ibid.* 93, No. 22, 10 (1932); E. E. Walker, *Chem. Trade J.* 88, 330 (1931); A. W. C. Harrison, *Paint Mfr.* 2, 243, 251 (1932); A. J. Norton, *Am. Paint J.* 15, No. 30, 22 (1931).
54. C. C. Campbell, to author, Jan. 17, 1947.
55. J. Marshall, *Chem. Ind.* 46, 19 (1940).
56. W. Smith, *J. Soc. Chem. Ind.* 20, 1075 (1901).
57. R. H. Kienle and C. S. Ferguson, *Ind. Eng. Chem.* 21, 349 (1929); B. S. Covell, *Plastic Prods.* 137 (June 1933); Marshall, *op. cit.*
58. *Chem. Mkts.* 25, 69 (1929); Campbell, *op. cit.*
59. O.P.D. *Reptr.* 87 (July 9, 1923), 64 (Mar. 26, 1926); *Fortune* 167 (Dec. 1934), 78 (Aug. 1935); Killeffer, *Ind. Eng. Chem.* 16, 995 (1924).
60. *Chem. Mkts.* 20, 52 (1927); O.P.D. *Reptr.* 74 (Nov. 14, 1927).
61. E. P. Partridge, *Ind. Eng. Chem.* 21, 1044 (1929); *Chem. Mkts.* 22, 421 (1928), 25, 69, 177 (1929).
62. *Chem. Mkts.* 25, 517 (1929).
63. *Ibid.* 19, 1274 (1926); Co. memo to author; Campbell, *op. cit.*
64. *Chem. Mkts.* 19, 1067 (1928).
65. Co. memo to author.
66. *Drug Chem. Mkts.* 16, 1259 (1925).
67. *Ibid.* 18, 1009 (1926).
68. *Chem. Mkts.* 21, 492, 560 (1927).
69. *Ibid.* 20, 374, 629 (1927); 21, 348 (1927).
70. *Ibid.* 20, 448 (1927).
71. *Ind. Eng. Chem.* 18, 297 (1926).
72. *Chem. Mkts.* 20, 55, 306, 418 (1927).
73. *Ibid.* 25, 519 (1929).
74. O.P.D. *Reptr.* 39 (Jan. 27, 1930).

## Chapter 22

### OILS AND PIGMENTS

PAINT INDUSTRY AWAKENED BY SYNTHETIC LACQUERS—TUNG OIL BOOM IN SOUTH—TITANIUM PIGMENTS BECOME TONNAGE ITEMS—PROGRESS IN ZINC PIGMENTS; LIGHT-RESISTANT LITHOPONE MADE—LEAD INDUSTRY MAINTAINED AS PRODUCTS MOVE INTO NON-PIGMENT FIELDS—MERGERS PROMINENT AMONG PIGMENT MAKERS—COLOR APPLIED IN CONSUMER GOODS; PAINT MATERIALS STANDARDIZED; RESEARCH PROMOTED.

NATURAL PIGMENTS and drying oils, traditional materials of the paint industry, were only obliquely affected by the arrival of the lacquers. With the boundless ambition of youth the nitrocellulose lacquer makers planned to capture what they called the "architectural market." Paints, they boasted, would soon be as obsolete as flintlock muskets. They were quite positive that they would conquer the technical difficulties associated with moisture that developed when their products were applied to wood and plaster. They have done so, but not nearly as quickly as they confidently expected, and they overlooked—or chose to ignore—the versatility of the ancient oil-pigment medium and the ability of the painters' unions to defend the paint brush against the spray gun.

Had a satisfactory, reasonably priced synthetic coating, suitable for interior and exterior use in the building trades, been perfected promptly, that dream of early conquest might have come true. But the time lag gave both chemists and painters an opportunity to throw up defenses against the invader. On the technological front, the battle has waged back and forth, but always upon an advancing front of better and cheaper coating materials of all types. On the labor front it has been a constant, bitter rear-guard delaying action, an amazingly successful battle against progress which has held up building costs and frequently even today prevents the use of the best and cheapest coatings.

The hero of the early technological skirmishes was tung oil. Empirical practice had long established that many drying oils are interchangeable in paint formulas, but until the early 1920's linseed was *the* paint oil. Walnut oil was slow-drying and prohibitively expensive; the fish oils, though cheap, had a persistently disagreeable odor; tung oil had an evil reputation for highly fluctuating price and unstable quality; soybean oil was almost unknown; and perilla and oiticia were available

only as laboratory samples which a few curious, scientific-minded investigators were analyzing and testing. Then linseed oil ruled supreme. Paint and printing ink, oilcloth and linoleum, the great drying-oil products, were all made by rule-o'-thumb methods. Formulas were recipes; processes were craft secrets. Both were jealously guarded and passed on from foreman to foreman who, with a well-developed protective instinct, were suspicious of new materials and highly contemptuous of new methods. To these sturdy craftsmen the chemist with his "book larnin' and highfallutin' notions" was anathema. It was easy for them to sabotage any improvements and they did so without mercy. Thus they had a stranglehold on the front office, and so long as the products were salable and profits satisfactory, the management adhered to a hands-off policy. All this is a familiar pattern in industry, one beautifully designed to smother progress and uphold *status quo*.

This unholy alliance of reaction and inertia was defeated by an unexpected partnership of the much maligned profit motive and highly praised scientific spirit. Again it is a familiar pattern, but one of progress. Especially was this so in the chemical industry, up to World War II, where the urge to greater profits inspired numberless organized, costly researches which brought to the market a multitude of cheaper and better products.

Tung oil and rosin make a fairly respectable varnish, a plain dollars-and-cents fact which became important when the synthetic lacquers appeared. Soon it was learned that phenolic resins could be modified \* by tung oil to become oil-soluble. Imports of tung oil grew from 87,000,000 to 119,000,000 pounds between 1923 and 1929, and the price doubled.<sup>1</sup> American manufacturers of paints and varnishes began to appreciate its virtues. At the same time they learned anew its peculiar vices. Due to careless collection and primitive processing, its quality was at best exceedingly variable and at worst the Chinese material was grossly adulterated. Always the supply was uncertain, and taking advantage of the unsettled political conditions, both Chinese dealers and American importers rigged the quotations.

After a long series of misadventures, the cultivation of tung trees had at last been established † with reasonable prospects of success in the

\* See Chap. 21. Later many other combinations of resins and different oils became important.

† In 1869 the captain of a Yankee clipper imported the first tung oil, a modest shipment worth \$62. Just after the turn of the century Dr. David Fairchild, plant explorer for the U. S. Dept. Agr., brought a bushel of tung nuts from the upper Yangtze Valley, and in 1906 several hundred yearling seedlings were distributed broadcast throughout the South. Most of these perished through neglect, improper cultivation, or because planted under unsuitable conditions of soil or climate. At Tallahassee, Fla., however, Capt. William H. Raines established a little grove, and in 1912 he gave 100 seedlings

neighborhood of Gainesville, Florida. A domestic source of supply would sidestep the speculation and sophistication of the Chinese market, and the 1924 convention of the American Paint & Varnish Manufacturers' Association voted unanimously to establish a cooperative tung plantation. The enthusiasm of the 70 firms which subscribed \$1,000 each to establish the American Tung Oil Corporation<sup>2</sup> was somewhat premature. The establishment of tung plantations upon a scale sufficient to provide appreciable quantities of oil took much longer than was anticipated, and in sidestepping their Chinese difficulties the paint manufacturers plunged headlong into a morass of different, but quite as difficult troubles. They were engulfed in strange, unsolved agricultural problems and their hopeful venture encountered administrative snags associated with a cooperative enterprise.

Nevertheless the American Tung Oil Corporation embodied a sound, constructive idea and its carefully planned program was in the main executed intelligently. From the first it set up double objectives: to run a commercial plantation which would be at once an example of approved cultural methods and an inspiration to encourage other planters, and at the same time to develop a nursery where seed and young stock would be available. The location was wisely fixed near Gainesville, close to the Florida Agricultural Experiment Station where the only scientific work on tung culture was being conducted and the first large-scale commercial planting, that of the Investment Company launched in 1922 by B. F. Williamson.\* Two plots of 200 and 70 acres were planted, and the officers, James H. McNulty of Pratt & Lambert, president, Ludington Patton and Henry L. Calman, vice-presidents, and P. H. Butler, secretary-treasurer, appointed Henry A. Gardner †

to a neighbor, Dr. Tennant Ronalds, whose Live Oaks Plantation is the birthplace of the American tung industry. Ronalds tried to awaken official interest by sending unhulled nuts to the Dept. in Washington and in 1914 he gave a bushel to L. P. Nemzek, chemist of the Paint Mfrs. Assoc. at Gibbsboro, N. J., who pressed them and made the first experiments. For the romantic details of the early days of this chemurgic development, see B. F. Williamson, *J. Chem. Educ.* 7, 9 (1930), *Ind. Eng. Chem., News Ed.* 5 (May 10, 1929), 8 (July 10, 1929); H. A. Hennessy, *ibid.* 8 (July 10, 1929); *O.P.D. Repr.* 21 (Nov. 24, 1930); Haynes, *Southern Horizons*, Chap. 6. For Williamson's account of early developments, see Appendix XLV.

\* Though C. C. Concanon of the Dept. Com. and H. A. Gardner rendered great services, the real father of the American tung industry is Bailey F. Williamson. He was born in Raleigh, N. C., in 1873, and after studying chem. at Cornell, was sulfuric acid mgr. at the Caraleigh Phosphate & Fertilizer Works, with the Golden Giant Mining Co. and Merchants & Planters Oil Co., and 8 yrs. with Armour & Co. before he became interested in growing pine and tung trees. From his nurseries came the first improved strains of tung trees and he has been a patient, enthusiastic teacher of better cultivation methods.

† Educated at Brown and U. Pa., Gardner has an hon. D.Sc. from Lehigh, 1932, and is a recognized authority on drying oils. He was born in Pawtucket, R. I., Oct. 12, 1882, and was for many yrs. pres. and dir., Inst. Paint & Varnish Research, Wash., D. C.

general manager and named Williamson the local operating manager.

As an inspiration the American Tung Oil Corporation functioned promptly and effectively.<sup>3</sup> One of its most sanguine and courageous backers, Benjamin Moore & Company, old paint manufacturers of Brooklyn, organized the Alachua Tung Oil Company, which planted 1,800 acres in 1924 and 500 additional in 1928.<sup>4</sup> The Moore project took the next inevitable but as yet untrodden step and installed an oil mill with a capacity of 60 gallons per hour, pressing nuts from its own groves and those of its neighbors. The tung idea was spreading rapidly. By 1929 there were 4,000 acres of tung trees planted in Florida and numerous plantations were being established in neighboring states. Two of the most important of these early ventures were backed by lumbermen with the idea of employing cut-over land; Lamont Rowlands and L. O. Crosby in the vicinity of Picayune, Mississippi.<sup>5</sup>

For a time the tung tree and its valuable oil were threatened with an overdose of publicity. Wide-awake real estate men misused the solid educational work of the Department of Commerce, the Florida Experiment Station, and the Paint & Varnish Manufacturers' Association as a factual foundation for skillful sales ballyhoo to sell tung land to optimistic investors in the future of this embryo chemurgic industry. Not all of the glib sales talk was deliberately misleading. Much was still to be learned about the optimum soil and climatic conditions so that hundreds of acres, quite unsuited for tung tree cultivation, were sold in ignorant good faith. Agricultural practices also were still experimental and many plantings failed because of improper cultivation and fertilization. These sincere mistakes did not help the situation, but providentially the tung plantation boom, which in the late twenties promised through inflation and chicanery to become an unworthy little brother of the orange grove and pecan orchard speculation, was deflated by the financial crash of 1929.

From the first, one characteristic of tung oil which particularly commended it to the coatings industry was its exceptionally rapid drying properties. These led to chemical investigations and comparison with other drying oils. Due to competition from quick-drying lacquers, the entire subject of driers in paints and varnishes became of lively interest and research,\* notably in metallic soaps, was unusually active.<sup>6</sup> During this period the cobalt driers became favorites just at the time when the only American production of this metal, by the chlorine method of decomposing and refining cobalt ores from Coniagas Reduction Com-

\* For further details, see W. F. Whitmore and M. Lauro, *Ind. Eng. Chem.* 22, 646 (1930); L. W. Ryan and W. W. Plechner, *ibid.* 26, 909 (1934); Bennett, *Review of Driers and Drying*.

pany's plant by the Niagara Alkali Company at Niagara Falls,<sup>7</sup> ceased to operate.

The rise of titanium compounds to an important place among the white pigments was a conspicuous event during the latter years of this period. The battle for recognition began in 1920 when the strong National Lead Company purchased control of the Titanium Pigment Company, and acquired a substantial interest in the Titan Company, A/S, of Norway, with American rights to its basic patents controlling titanium paint pigments.<sup>8</sup> The process originally consisted of dissolving titanium ore in sulfuric acid, crystallizing out the ferrous sulfate, and then hydrolytically precipitating titanium oxide on an inert carrier, washing to remove iron salts and acid, and finally calcining in rotary kilns.<sup>9</sup> The first pigment offered commercially was titanium precipitated on barium sulfate,<sup>10</sup> trade-named Titanox-B, followed in 1925 by a calcium base pigment (30 per cent titanium dioxide; 70 per cent calcium sulfate), sold as Titanox-C, and shortly afterwards by pure titanium dioxide, Titanox-A.\* The desirable properties of these new white pigments, especially their high hiding power, excellent color, resistance to sunlight and sulfurous gases, and their chemical inertness, were particularly accentuated in pure titanium dioxide. By 1927 titanium pigments were moving in carload lots.<sup>11</sup>

Rapid progress in improving quality and lowering costs, with accompanying price reductions, stimulated the demand for these newcomers after 1927, but as early as 1923 the Titanium Pigment Company began negotiating for the purchase of the plant of the Mineral Refining & Chemical Corporation at St. Louis.<sup>12</sup> After thorough revamping, this plant, which had the advantage of an excellent location for the economical supply of its raw materials (imported ilmenite ores and sulfur by barge up the Mississippi; barytes and lime from the near-by Missouri mines) opened in 1924, the first step in a program of expansion.<sup>13</sup> In 1924 the capital of Titanium Pigment was increased from \$4,300,000 to \$5,000,000, to handle this growth, the additional stock being sold to National Lead.<sup>14</sup>

Since 1920 National Lead had been working closely with the Titan Company, exchanging technical information, developing new markets, and pooling patents, and in 1927 it exercised its option to purchase the Norwegian company.<sup>15</sup> Almost simultaneously it bought the Société Industrielle du Titane, its patent rights, and its plant at Clichy, France.† Evans McCarty, vice-president of the United Lead Company and

\* Later, in 1935, Titanox-L, lead titanate, was offered by the same company.

† These purchases were made upon an unannounced cash basis, the capitalization of National Lead having been increased the April previous from \$50,000,000 to \$100,000,000. [See *Chem. Mkts.* 21, 883 (1927).]

member of the executive committee of National Lead, had successfully executed these purchases. He now went to Germany to negotiate with the I.G. for the manufacture and marketing of titanium pigments in Central Europe. A jointly owned company was formed with a plant at Cologne operating on Norwegian titanium ores.\*

This formidable amalgamation of National Lead's foreign and domestic interests in titanium pigments did not dismay competition nor discourage progress. February 1928, the Commercial Pigments Corporation began production of titanium dioxide pigment in a plant at Curtis Bay, Maryland, adjacent to U. S. Industrial Alcohol, with a daily capacity of 10 tons plus 40 tons of by-product copperas (ferrous sulfate). The operation was based on a process developed by Dr. Joseph Blumenfeld of the Société des Produits Chimiques des Terres Rares of Paris.<sup>16</sup> The new company had purchased for \$1,250,000, plus a royalty, the American patent rights, together with a cooperative interest in all discoveries and technical improvements made by the French company and foreign licensees of the Blumenfeld process, and a substantial interest in Travancore Minerals Company, a British corporation owning licenses to work the ilmenite-bearing sands in India. Commercial Pigments, its property, patent rights, and interests, were all purchased outright, October 3, 1929, by the Commercial Solvents Corporation by an exchange of 10 shares of its common stock for 9 shares of the Class B stock of the pigment firms;<sup>17</sup> 124,440 new shares were issued for this transaction. This same year a new method of preparing titanium dioxide was described by F. von Bichowsky, based on converting the nitride by the use of nitric acid and catalysts.<sup>18</sup> It was never commercially adopted. Silicon esters dissolved in a suitable solvent were also proposed at this time as a perfect vehicle for titanium pigments.<sup>19</sup>

Lithopone, the older modern rival of the classical white pigments, lead carbonate and zinc oxide, sold in greatly increased quantities during the twenties, outstripping all others and reaching 206,000 tons in 1929. This year the paint, varnish, and lacquer industries consumed 73 per cent, floor coverings and textiles, 18 per cent, and rubber, 3.5 per cent, which was a distinctly greater increase than that of zinc oxide, while lead pigments markedly declined. Its conspicuous fault of darkening on exposure to moisture and sunlight having been practically eliminated,† lithopone became more and more popular, particularly

\* Subsequently similar arrangements were made with Imperial Chemical Industries through the British Titan Products Co., and in the early 1930's a Canadian subsidiary, Canadian Titanium Pigments Co., was organized. [See W. W. Plechner, *Chem. Ind.* 46, 438 (1940).]

† About 1920, by the process patented by the New Jersey Zinc Co. See Vol. III, p. 99, also J. H. Goshorn and C. K. Black, *Ind. Eng. Chem.* 21, 348 (1929); W. A. Wood, *J. Soc. Chem. Ind.* 49, T300 (1930); *Chem. Trade J.* 90, 377 (1932).

in interior flat wall and enamel paints and some outside paints, replacing white lead, whose toxicity was now recognized, and zinc oxide. Furthermore, it firmly established itself as the favorite basic pigment of the linoleum manufacturers and its use in rubber compounding, due to its good physical properties and zinc content, showed a healthy increase.<sup>20</sup> In 1927 the suit of the New Jersey Zinc Company *vs.* the Krebs Pigment & Chemical Company, charging infringement of the patent covering the manufacture of lithopone to control its photogenic fault, was settled out of court. Krebs joined du Pont, Grasselli, Sherwin-Williams, Chemical & Pigment (Glidden), United Color & Pigment, and Eagle-Picher as a licensee. Subsequently all production in England was under similar license.<sup>21</sup> That same year Krebs engaged as consultants for an extended research in lithopone production, two former New Jersey Zinc chemists,<sup>22</sup> J. A. Singmaster and Frank G. Breyer.\* Cadmium lithopone developed by Breyer and his coworkers at New Jersey Zinc, in which the zinc of the ordinary product is replaced by cadmium, appeared commercially in 1922, winning attention for its brilliant, fast yellow color.<sup>23</sup>

The advent of barium and calcium-extended titanium pigments toward the end of this period began to compete seriously with lithopone. Some manufacturers introduced a titanated lithopone grade containing 15 per cent titanium dioxide and of comparable covering power, which was covered by patents subsequently acquired by du Pont, whose lithopone research was headed by Dr. J. E. Booge.†

Three important developments in the zinc oxide field occurred during this period. One was the development of the mechanical Wetherill furnace for the production of zinc oxide by the New Jersey Zinc Company, which greatly increased recovery, reduced labor, and improved its uniformity in paint-making and rubber-making. Another was the development of the St. Joseph Lead Company's electrothermic process for zinc oxide which was influential in materially displacing the French process oxides. The third was the production by New Jersey Zinc, of very finely divided zinc oxide known as Kadox and very active in rubber.

These years were also noted for technical developments in zinc metal-

\* Both left N. J. Zinc in 1927 to form Singmaster & Breyer. It was their lithopone patents that were licensed to U. S. and foreign manufacturers. Singmaster, born Aug. 7, 1878, and educated at Gettysburg (M.A., 1898), is also known for his rayon delustering process. Breyer, born Dec. 24, 1886, and educated at Johns Hopkins (M.A., 1910), is author of some 50 patents in the pigments and metallurgical fields. He received the Modern Pioneer award in 1940.

† "Dr. Booge subsequently played a leading part in the development of  $\text{TiO}_2$  pigments and later became chem. dir., Pigments Dept., of du Pont." (F. H. Weismüller, to author, Feb. 10, 1947.) He was born in Iowa, 1890, educated at U. Iowa (A.B., 1914) and Columbia U. (Ph.D., 1916) in both of which he taught, and joined du Pont in 1917.



lurgy. Flotation methods, introduced in 1921 and becoming important about 1925, made it possible to save zinc values in complex zinc-lead ores previously discarded.<sup>24</sup> The electrolytic method of zinc refining also became firmly established. The misleading assumption that in the electrodeposition of zinc the sulfuric acid formed at the anode must be neutralized to prevent solution of the metal at the cathode having been dissipated by U. C. Tainton in England, Frederick Laist \* at Anaconda, and F. W. Guernsey at Trail, British Columbia, cleared the way for this process.<sup>25</sup> Only Anaconda recovered zinc electrolytically—from which it produced various French process zinc oxides—† until 1927, when the Bunker Hill & Sullivan Company installed a plant using the Tainton process at Kellogg, Idaho. The following year the Evans-Wallower Zinc Company applied the same method to Joplin ores at East St. Louis, adjacent to the Monsanto sulfuric acid works.<sup>26</sup> Evans-Wallower at this time purchased from Eastern Electrolytic Zinc, Inc., all its properties and assets, including Tainton's United States patents, for \$100,000 cash and 115,000 shares of common stock, with an option to purchase an additional 10,000 shares at \$10 per share.<sup>27</sup>

This country furnished about two-thirds of the world's zinc, and American producers seem to have been remarkably disturbed over a paltry recovery of the metal from Spanish pyrites imported by sulfuric acid manufacturers in the Baltimore district. Cinders from their operations were sent to the Pyrites Company at Wilmington and after a chloridizing roasting, followed by leaching with acid, the copper and zinc values were both recovered, the latter being shipped to near-by lithopone manufacturers. Although only 20 pounds of zinc were so extracted daily, the Superior Zinc Corporation, through Levi Cooke, argued<sup>28</sup> for tariff protection. No doubt this was a protest "on principle," though the threatening European Zinc Cartel, organized in May 1928, was breaking up even as this testimony was being taken in Washington.<sup>29</sup> That short-lived price-and-market agreement had called forth from the American Zinc Institute a formal denial of any collaboration with the European producers,<sup>30</sup> a superfluous defense, it would seem, since the European cartel had been organized immediately after the

\* Laist, born in Cincinnati, 1878; B.S., U. Calif. (1901); D.Sc., Colo. Sch. Mines (1921); was chief chem. at Anaconda's Great Falls Reduction Works, 1914-16, and gen. metal. mgr. since that date. He is dir., Butte Copper & Zinc Co. and Electrolytic Zinc Process Co., and has been awarded the gold medal of the Am. Inst. Min. Met. Engrs.

† "In 1921 G. S. Brooks and F. O. Case, formerly with New Jersey Zinc Co., started experimental work on these oxides at the East Chicago, Ind., plant of Anaconda. With the help of Wm. Wraith, pres. of the subsidiary, International Lead Refining Co., and F. Laist, French oxide units were erected at East Chicago in 1922 and at Akron in 1923. Additional units were later added and in 1925 American process units were installed at both plants, the total annual capacity being 36,000 tons." (F. O. Case, to author. Feb. 21, 1927.)

formation of a Webb-Pomerene corporation,<sup>31</sup> the Zinc Export Association,\* by American producers.

Inroads of lithopone and various titanium pigments cut down the production of white lead during the twenties.† However growing sales of litharge and red lead to storage battery manufacturers and increasing use of the metal in the electrical industry, particularly for power cable sheathing and as a construction material in chemical apparatus, maintained the general prosperity of the lead mining industry.<sup>32</sup> While demands for the metal and its salts were increasing rapidly, there were portents that three of the world's great lead districts, the Spanish, the Australian, and the Coeur d'Alene, had all passed their period of greatest productivity.<sup>33</sup> On the other side of the ledger, the successful introduction of flotation methods, which made a reasonably pure selective separation by a relatively simple process, made it possible to operate profitably many mines which would have been closed due to low prices of both lead and zinc and the signs of failing reserves.<sup>34</sup> At the same time the Harris process,‡ consisting of the oxidation of the impurities in lead to a molten condition by circulating through it an alkali in the presence of a solid oxidizing agent, contributed to the ease and economy of desilvering and dezincing methods.<sup>35</sup>

A newcomer among the lead pigments was finely divided lead suboxide ( $Pb_2O$ ) which, suspended in linseed oil, was introduced for spray and brush application under the trade name Subox.<sup>36</sup> An improved white lead was made early in the twenties by Dr. John A. Schaeffer, § B. S. White, and J. H. Calbeck in the laboratories of Eagle-Picher, a product which was known as "super sublimed" white lead.<sup>37</sup> Late in the decade a process discovered by Dr. George E. Kingsley for the direct production of white lead and chrome yellow from galena by a continuous chemical process, was placed in experimental operation by the General Reduction & Chemical Company at Newark,<sup>38</sup> but did not prove successful.

By concentrating respectively on mining and refining, St. Joseph Lead and American Smelting & Refining aimed at greater efficiency, particularly in working low-grade ores in the Missouri district. In 1923 St. Joseph bought the adjoining mines of the Federal Lead Company,

\* The first officers were A. J. McKay, pres.; B. W. Zimmer, Chas. T. Orr, and A. E. Bendelari, vice-pres.; W. A. Ogg, treas.; and C. H. Klaustermeyer, secy. Members at the time of incorporation were American Metal Co., American Zinc, Lead & Smelting Co., Athletic Mining & Smelting Co., Eagle-Picher Lead Co., Ft. Smith Spelter Co., Grasselli Chemical Co., Hegeler Zinc Co., Illinois Zinc Co., Matthiessen & Hegeler Zinc Co., Quinton Spelter Co., United Zinc Smelting Corp.

† For production of lead and other pigments, 1923-29, see Appendix XLVI.

‡ Brit. Pat. 213,638 (1922); see also *Min. & Met.*, Apr. 1924.

§ Schaeffer, who joined Eagle-Picher in 1911, resigned as vice-pres. and dir. research in 1935 to become pres. of his Alma Mater, Franklin & Marshall Coll.

a subsidiary of the refining company, for \$10,000,000 and a 30-year smelting contract for two-thirds of all ore from all its mines in this district, including the Doe Run Lead Company owned by St. Joseph.<sup>39</sup> With its contacts with both Hecla and Bunker Hill & Sullivan as sales agent, St. Joseph was now selling half of the lead mined in the United States, and assured of ore supplies for its refineries, American Smelting & Refining continued to be the largest refiner in this country. In 1928 Eagle-Picher also extended its mining operations when the subsidiary Consolidated Lead & Zinc Company purchased for \$400,000 the holdings of Domado Mining Company.<sup>40</sup>

Among the pigment manufacturers the merger era was even more sharply marked. In 1923 the Mineral Refining & Chemical Corporation, with a plant on the River des Peres near St. Louis, became financially involved \* and Casper P. DeLore, president of the C. P. DeLore Company, who held a \$150,000 promissory note six months overdue, took over the plant and continued to produce barytes, whiting, and lithopone.<sup>41</sup> Next year the United Color & Pigment Company made a \$60,000 addition to its Newark, New Jersey, operation<sup>42</sup> and three years later took its sales in the important paint district of Cleveland out of the hands of J. C. Drouillard Company, establishing its own office under B. V. Hendrickson.<sup>43</sup>

West Coast activities were considerable. In 1921 the Synthetic Iron Color Co. was organized by Norman M. Zoph† to manufacture iron oxide colors by the so-called Ferrite process which he and Russell S. Penniman had developed. Three years later it purchased additional land at Richmond and erected a new, modern plant.<sup>44</sup> Zoph had been previously associated with the National Ferrite Company at Farmingdale, New York, and had withdrawn with rights to develop the process in the territory west of the Rocky Mountains. In 1922 the Magnetic Pigment Company bought the National Ferrite plant and patents, and continued to develop yellow, brown, and red oxide pigments in a new plant built in 1923 at Trenton, New Jersey. So popular were these colors that by the late twenties a considerable export business was enjoyed, and the I.G. began manufacturing a yellow under a German patent that was later adjudicated to be an infringement of one of Magnetic Pigment's patents.<sup>45</sup> In 1928 the well-known dry color and pigment firm of C. K. Williams Company of Easton, Pennsylvania,

\* In the voluntary bankruptcy liabilities were listed at \$1,481,322; assets at \$35,421. Officers were Jose Marimon, formerly pres. of the Spanish Bank of Havana, pres.; Charles A. Houts, St. Louis atty., vice-pres.; Thos. J. Coule, secy.; Louis Nolte, mfg. jeweller who was Comptroller of St. Louis, treas.; E. Buxo Canel, gen. mgr.

† With a B.S. in mining eng. from U. Calif. (1907), Zoph, after serving several copper companies as chem., became color plant supt., West Coast Kalsomine Co. (1915-21), later Wesco Waterpaints, Inc.

established in 1878, opened a plant at Emeryville, operated by a wholly owned subsidiary, the C. K. Williams Company of California.<sup>46</sup>

The last year of the decade saw several mergers. The Kentucky Color & Chemical Company of Louisville, which in 1926 made a \$60,000 addition to its plant,<sup>47</sup> purchased the National Ultramarine Company\* of Norwood, Ohio.<sup>48</sup> Three dry color companies were consolidated by Bernard R. Armour of American Aniline Products and Heyden, when he formed the Ansbacher Insecticide Company, formerly controlled by A. B. Ansbacher,<sup>49</sup> with which he shortly afterwards amalgamated the G. Siegle Corporation of America by an exchange of stock.<sup>50</sup> Three months later, the new company took over the Contex Color Company, makers of dry and lake colors at Paterson, New Jersey, and successor to the Cosmic Color Company of Newark.<sup>51</sup> Also in 1929, the E. I. du Pont de Nemours & Company bought the Krebs Pigment & Chemical Company by issuing 19,999 shares of nonvoting debenture stock, par value \$100, and 20,823 shares of voting common stock at par, \$20.<sup>52</sup>

In the merger movement, too, was the consolidation in 1926 of the two associations in the paint and varnish fields. On October 18, the National Varnish Manufacturers' Association and the Paint Manufacturers' Association of the United States united as the American Paint & Varnish Manufacturers' Association.<sup>53</sup> The first president was Frank P. Cheeseman of Cheeseman, Elliott Company; the vice-presidents were A. D. Graves of Pratt & Lambert and J. Sibley Felton of Felton, Sibley & Company; and the secretary-treasurer was George B. Heckel, publisher of *Drugs, Oils & Paints*.† Also in line with the times was the organization in 1925 of the Dry Color Manufacturers' Association, whose original roster included A. B. Ansbacher & Company, Brooklyn Color Works, E. I. du Pont de Nemours & Company, Federal Color Laboratories, Fine Colors Company, Morris Herrmann & Company, H. Kohnstamm & Company, Kentucky Color & Chemical Company, Fred L. Lavanburg Company, John T. Lewis & Bro. Company, Alston-Lucas Paint Company, Spencer Lucas Company, William Macher & Sons, Max Marx Color & Chemical Company, Pfeiffer Color Company, G. Seigle Corporation, Sun Color & Chemical Company, Paul Uhlich & Company, Ultro Chemical Corporation, Western Dry Color Company, A. Wilhelm Company, and Henry Woods Sons Company.<sup>54</sup>

The 1922-29 period saw a great increase in the use of color on consumer goods and the introduction of new types of brilliant pigments of reasonable permanency. The sales appeal of color for automobiles,

\* Purchase of Heller & Merz by Calco brought this company into the ultramarine field.

† The original dir., in addition to the officers, were Frank L. Sulzberger, Lawrence Phillips, F. M. Brininstool, W. R. Carnegie, H. A. Melum, R. W. Levenhagen, W. P. Allen, Harry A. Hall, and E. H. Hancock.

kitchenware, and many other household items, and its increased use in the graphic arts, especially magazine advertising, catalogs, and packages, led to many practical improvements in the formulation and application of colors. The phosphotungstic and phosphomolybdic acid colors were developed at this time, as well as the resinated organic toners which were an improvement over many of the corresponding nonresinated ones. Also many paint formulators began using so-called C.P. colors because of their greater economy and versatility compared with the older reduced types.<sup>55</sup>

Quite as characteristic of these years was the awakened interest in the chemistry of paint materials and the drafting the first detailed standards. The chemical staffs of pigment and other paint material producers and of many coatings companies, whose sole activities had previously been testing and analyzing, began investigations into oils, solvents, colors, this recognition of the essentially chemical character of the industry having been driven home by the nitrocellulose lacquers. As in the chemical industry, research by New Jersey Zinc, Spencer-Kellogg, National Lead, and their followers reached beyond the laboratories and became technical service. In 1926 the important Imperial Color Works,\* Glens Falls, New York, doubled its laboratory and staff and offered its customers aid in solving their problems.<sup>56</sup> Standardization of coatings started in 1923 with the crusade of the Department of Commerce to simplify the number of grades† of all sorts of manufactured wares,<sup>57</sup> and in 1927, when Committee D-1 on Protective Coatings for Structural Materials of the American Society for Testing Materials issued a long series of standard tests ranging all the way from the specific gravity of pigments to methods of analysis of all types of dry colors, lakes, toners, and pigments.<sup>58</sup> Far-reaching as were the direct effects of the revolution initiated by organized research in coating materials and processes, the changed spirit of the coatings industry was quite as important to the future course of developments during the years of the Great Depression.

\* Now Imperial Paper & Color Corp.

† The chief effort was to reduce the number of shades in ready-mixed paints, and the industry agreed to limit the floor paints to 8 shades, house paints to 32, flat wall paints to 16, enamels to 10, porch paints to 6, roof and barn paints to 4, shingle stains to 12, oil stains to 8, varnish stains to 8, spirit stains to 14, carriage paints to 8, while oil colors were reduced to 32 shades and tints, architectural varnishes to 10, and marine varnishes to 4. [See *Pharm. Era* 56, 514 (1928).]

#### REFERENCES

1. *O.P.D. Reprtr.* 21 (Nov. 24, 1930).
2. *Drug Chem. Mkts.* 14, 21 (1924).
3. S. T. Fleming, *Chem. Mkts.* 20, 541 (1927); H. A. Gardner, *Ind. Eng. Chem.* 19, 266 (1927) & *O.P.D. Reprtr.* 30 (Aug. 18, 1930); *Chem. Met. Eng.* 34, 266 (1927).
4. *Ind. Eng. Chem., News Ed.* 8 (Jan. 10,



A. J. L. MONITZ



SAMUEL A. SALVAGE



GEORGE W. MIDDLETON



D. M. BALSAM



HIRAM S. RIVITZ



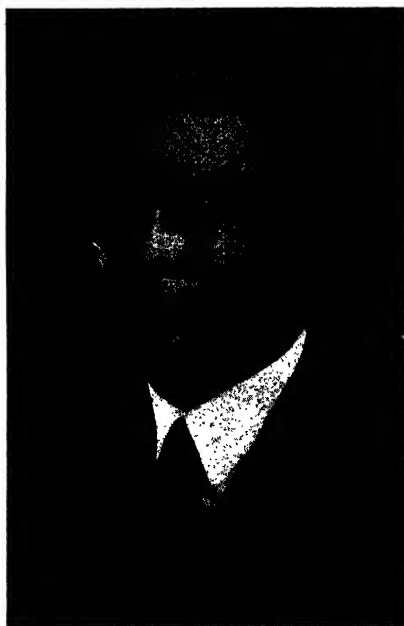
*Chemical & Metallurgical Engineering*

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*Rayon Textile Monthly*

R. S. FULLER, JR.



LELAND LYON

- 1929), 8 (July 10, 1929); *O.P.D. Reprtr.* 21 (Nov. 24, 1930).
5. *O.P.D. Reprtr.* 21 (Nov. 24, 1930); Haynes, *Southern Horizons*, p. 101.
6. J. S. Long, *Am. Paint & Varnish Mfrs. Assoc., Sci. Sect., Circ. No. 319*, 598 (1927); A. C. Elm, *Ind. Eng. Chem.* 26, 386 (1934); C. C. Concannon, *Bur. For. Dom. Com., Trade Prom. Ser. No. 133*, 42 (1932).
7. *Min. Ind.* 1923, 161.
8. W. W. Plechner, *Chem. Ind.* 45, 439, 540 (1940).
9. E. K. Moore, *Ind. Eng. Chem., News Ed.* 19, 300 (1941).
10. Plechner, *op. cit.*
11. R. L. Hallett, *Am. Paint J.* 12, No. 10, 11 (1928); E. W. Boughton, *Chem. Mkts.* 25, 380 (1929).
12. *Min. Ind.* 1923, 675.
13. Moore, *op. cit.*
14. *O.P.D. Reprtr.* 38 (Apr. 4, 1927).
15. *Chem. Mkts.* 20, 554 (1927), 21, 279, 883 (1927); *Min. Ind.* 1927, 584.
16. *Chem. Met. Eng.* 35, 427 (1928); *Poor's Manual of Industrials*, 1930, p. 554.
17. Co. memo to author; *Chem. Mkts.* 25, 401 (1929); *Poor's Manual, op. cit.* For details of financial transaction, see Civil 26-258, U. S. vs. National Lead et al., 7th Dist. N. Y.
18. *Ind. Eng. Chem.* 21, 1061 (1929).
19. G. King, *J. Oil & Colour Chem. Assoc.* 13, 28 (1930).
20. *Chem. Ind.* 19, 263 (1926); N. F. Budgen, *Ind. Chemist* 2, 169 (1926); *Min. Res.* 1929, II, 213.
21. *O.P.D. Reprtr.* 21 (July 4, 1927); F. J. Breyer, to author, Feb. 4, 1947.
22. *Chem. Mkts.* 21, 121 (1927).
23. R. W. Cooper, *J. Soc. Chem. Ind.* 46, 552 (1927).
24. J. C. Bailar, Jr., *J. Chem. Educ.* 10, 102 (1933); *Min. Ind.* 1926, 696.
25. O. C. Ralston, *Trans. Am. Electrochem. Soc.* 51, 129 (1927).
26. C. W. Cuno, *Chem. Mkts.* 28, 253 (1931).
27. *Poor's Manual, op. cit.* p. 1687.
28. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 3, Jan. 18, 1929, p. 2133.
29. *O.P.D. Reprtr.* 31 (Dec. 9, 1929); *Min. Res.* 1929, I, 713.
30. *Chem. Mkts.* 24, 60 (1929).
31. *Ibid.* 20, 788 (1927).
32. O. C. Harn, *Chem. Met. Eng.* 33, 37 (1926); *Min. Res.* 1928, I, 615.
33. *Min. Ind.* 1924, 423.
34. *Min. Res.* 1927, I, 345.
35. *Min. Ind.* 1928, 387.
36. *Min. Res.* 1927, I, 345.
37. J. H. Calbeck, *Trans. Am. Inst. Chem. Engrs.* 16, Pt. II, 13 (1924).
38. *O.P.D. Reprtr.* 29 (June 3, 1929); basic patent, Can. 238,665 (1924).
39. *Min. Ind.* 1923, 400.
40. *Ibid.* 1928, 373.
41. *Drug Chem. Mkts.* 12, 409 (1923).
42. *Ibid.* 14, 255 (1924).
43. *Chem. Mkts.* 19, 747 (1926).
44. *Drug Chem. Mkts.* 14, 19 (1924).
45. Peter Fireman, to author, Jan. 16, 1947.
46. *Chem. Mkts.* 20, 560 (1927).
47. *Drug Chem. Mkts.* 18, 1131 (1926).
48. *O.P.D. Reprtr.* 20 (June 10, 1929).
49. *Chem. Mkts.* 24, 393, 407 (1929).
50. *Ibid.* 25, 297 (1929); *Poor's Manual, op. cit.* p. 3408.
51. *Chem. Mkts.* 24, 633 (1929); 25, 629 (1929).
52. *Ibid.*; *Com. Fin. Chron.* 128, 3690 (1929).
53. *Chem. Mkts.* 19, 997 (1926).
54. *Drug Chem. Mkts.* 17, 1057 (1925).
55. S. I. Karpeles, to author, Jan. 30, 1947.
56. *Drug Chem. Mkts.* 18, 707 (1926).
57. *Pharm. Era* 56, 514 (1928).
58. *Am. Soc. Testing Materials, Standards*, 1927, Pt. II; also see *Proc. Am. Soc. Testing Materials* 27, Pt. I, 850, 860 (1927).



## Chapter 23

### RAYON AND OTHER TEXTILES

CHEMICAL SURPLUSES CONSUMED AS RAYON OUTPUT INCREASES 15-FOLD WITHIN DECADE—TEXTILE INDUSTRY RELINQUISHES OWN RAYON PRODUCTION—THREE BIG FOREIGN MAKERS ENTER AMERICAN FIELD GRAVITATING SOUTHWARDS—ACETATE RAYON COMPETES WITH VISCOSE, CUPRAMMONIUM REVIVED—RAYON MAKERS SWITCH FROM COTTON LINTERS TO WOOD PULP CELLULOSE; EXPLORE FARM WASTES—RAYON TRADE ASSOCIATION ORGANIZED; STUDIES STANDARDS AND SPECIFICATIONS.

THE WORLD-WIDE RAYON SITUATION was summarized by Samuel Courtauld in the *London Times*:<sup>1</sup> "Production has overtaken consumption and selling prices are now really competitive."

This was in the spring of 1927, and he sagely noted that at this point the manufacture of artificial fibers had achieved maturity as an industry. He added some pungent comments on the effects of this new economic status.

Courtauld was a competent analyst, the head of the third generation of the exceedingly profitable silk manufacturing firm of Courtaulds, Ltd. He had been active in British politics where he had earned the nickname, "Gloomy Sam." Despite his silk background and his popular reputation as a thoroughgoing pessimist, he foresaw a brilliant future for "imitation silk," or it is possible that he fearfully anticipated a successful rival of real silk. Whatever his motives, it was his courageous, persistent faith and his money that established the viscose process both in England and this country. Instinctively he was jealous of the quality of synthetic fibers, even those from his competitors, and he rejoiced that with sufficient plant capacity to meet current requirements it would become exceedingly difficult to sell those inferior fabrics which had given artificial silk a bad name among the trade and the public. He foresaw quite clearly all the advantages of lower price and higher quality. He did not shrink from the sharper competition these new conditions would surely bring, but he welcomed them as bringing also new opportunities. With unusual perspicacity, he named the birthday and sketched the future of the new era.

After a long-delayed, fumbling start,\* the rayon industry in this

\* See Vol. III, p. 374; also H. W. Ambruster, *Rayon* 10 (Dec. 30, 1925); Haynes,

country grew exuberantly after the First World War. From 8,200,000 pounds in 1919 to 130,450,000 in 1929<sup>2</sup> represents an annual average increase of some 12,000,000 pounds, one of the most rapid expansions recorded in American economic history. At the close of the war a single, foreign-owned company was the sole producer. At the close of the twenties, the industry consisted of 15 active firms, 2 inactive, and 2 experimental, operating the viscose, the acetate, the cuprammonium, and the nitrocellulose processes. Of the active firms 11 were American-owned, only 4 controlled by foreign interests.\* From an insignificant international position the United States had leaped to first place, both as producer and consumer of synthetic fibers, contributing more than a quarter of the world's output and accounting for more than a third of its consumption. Thus when Courtauld found that world supply balanced demand, domestic production in this, the greatest rayon market, was still being eked out by 25,000,000 pounds of imported yarns. This urgent pressure to expand was shortly to be relieved somewhat by the depression, but in 1927 the chemical industry gratefully applauded when Harrison Howe told the American Society of Mechanical Engineers<sup>3</sup> that cellulose had replaced coal tar as the outstanding raw material, for cellulose meant an enormous consumption of chemicals in processing.

Between 1921 and 1930 it was estimated the rayon industry consumed 1,086,000,000 pounds of sulfuric acid, 750,000,000 pounds of caustic soda, 235,000,000 pounds of carbon bisulfide, 46,000,000 pounds of acetic acid and anhydride, and 20,000,000 pounds of acetone.<sup>4</sup> These impressive figures help to explain why the chemical industry was able so promptly to employ fully its expanded, war-built capacity. But they go deeper than this.

The rayon industry's demand encouraged the technical shift to contact sulfuric acid and supported the introduction of synthetic processes for acetic acid and acetone. In the electrolytic alkali industry, on the other hand, it created a serious unbalance that threatened to become critical. Nor was it only in these big-tonnage chemicals that rayon requirements were felt. In the single year of 1927 it was estimated that the rayon and textile industries between them used 50,000,000 pounds of hydrochloric acid, 1,200,000 pounds of oxalic acid, 2,000,000 wine gallons of denatured alcohol, 10,000,000 pounds of aluminum sulfate, 10,200,000 pounds of sodium bichromate, 16,000,000 pounds of sodium silicate, 18,000,000 pounds of zinc oxide, and 184,000,000 pounds of sodium sulfate.<sup>5</sup> Figures of this magnitude make the chemical require-

*This Chemical Age*, Chaps. 16 and 17; Hard, *Romance of Rayon*; Avram, *Rayon Industry*; Mauersberger and Schwartz, *Rayon . . . Handbook*.

\* See Appendix XLVII for U. S. rayon companies, 1929, their plants and production.

ments of the whole coal-tar industry—for all its technical importance—seem a Lilliputian enterprise. They explain, too, both how and why American chemical production pyramided through the twenties.

Skyrocketing production to meet an insatiable demand inevitably attracted new producers. These were piping times indeed, when almost any producer of rayon was guaranteed success. Quality, as Courtauld complained, suffered, for the immediate, very profitable objective was to fill orders. And yet this strident call for more and more rayon had beneficial effects. It strengthened the more efficient companies and it encouraged the introduction of new types of synthetic fibers.

In 1922 there were four American producers of rayon: Viscose, the pioneer whose output exceeded the other three added together; Tubize Artificial Silk Company, making nitro rayon at Hopewell, Virginia; the Industrial Fibre Corporation, now the Industrial Rayon Corporation of Cleveland; and du Pont Rayon, then known as the du Pont Fibersilk Company, with a plant just opened at Buffalo. Thenceforward to 1929, the chronicle is crowded with more plants, new companies, and still more plants.

The Viscose Company, which already had plants at Marcus Hook and Lewistown, Pennsylvania, and Roanoke, Virginia, authorized in 1925 a new one at Parkersburg, West Virginia, to cost \$10,000,000.<sup>6</sup> This was built during 1926 and came into operation in 1927 with an annual capacity of 12,000,000 pounds. In 1928 the Roanoke plant was the largest in the world, with a capacity of 20,000,000 pounds a year.<sup>7</sup>

Du Pont was hardly in operation at Buffalo before Leonard A. Yerkes, president of its Fibersilk subsidiary, completed negotiations—for one stage badly enmeshed in red tape and legal technicalities—for the purchase of the Old Hickory powder plant from the Nashville Industrial Corporation and officials of the War Department, for \$650,000.<sup>8</sup> Keeping the village as a nucleus, du Pont built a new \$4,000,000 plant which came into production early in 1926. Within two years the company purchased a 517-acre site at Amphill, near Richmond, Virginia, and began the construction of a \$10,000,000 plant.<sup>9</sup> That same year a second unit was completed at Old Hickory and a third contracted for at an estimated cost of \$4,000,000, which brought the production at Nashville to over 1,250,000 pounds a month and made Tennessee the largest rayon-producing state.<sup>10</sup> In 1929 the original (1926) bucket-spinning unit at Buffalo was doubled.<sup>11</sup>

The Industrial Rayon Corporation, second oldest producer in the country, had gotten off to a poor start and stumbled along until 1926 when there was a reorganization. Established in 1916 as the American Borvisk Company, subsidiary of Borvisk Kunstseiden of Hertzberg,

Germany, it became the Industrial Fibre Corporation of America in 1920, when the American Borvisk interests combined forces with Snia Viscosa of Italy.<sup>12</sup> The ownership became 100 per cent American in 1925, when the Industrial Rayon Corporation was formed by a syndicate mustered by Walter W. Birge and Samuel Ungerleider to buy out the Italian interests \* in Industrial Fibre.<sup>13</sup> A new corporation, Industrial Rayon Corporation, was formed in Delaware with \$60,000,000 capital and the foreign holdings exchanged for 394,000 shares.<sup>14</sup> The new management cleaned house both in the Cleveland plant, which was revamped and enlarged,<sup>15</sup> and in personnel, entirely reorganizing the administrative and sales departments and engaging a new chemical staff which went to work to improve both the operations and the product. Birge was president till May 1926 when Bertrand R. Clarke, vice-president of Tubize Artificial Silk Company, was named in his place, only to be succeeded a year later by Hiram S. Rivitz. Their associated Industrial Fibre Throwing & Dyeing Company was consolidated and the capacity of the original plant was doubled in 1926.<sup>16</sup> In 1929 a new plant, the most up-to-date then built in this country, was opened October 1, at Covington, Virginia, with a capacity of 6,000,000 pounds of viscose yarn a year, virtually doubling the company's output.<sup>17</sup>

To these original three, eleven other viscose plants were added before 1930. The first, the Acme Rayon Company of Cleveland, came into production in 1924, though it had been originally organized in 1920,<sup>18</sup> and 1925 saw two newcomers. The Belamose Corporation with a plant at Rocky Hill, Connecticut, came into operation January 1, backed by a combination of American and Belgian interests.<sup>19</sup> The Skenandoa Rayon Corporation was something new in rayon enterprises, backed by textile interests which took its entire output. When the Skenandoa Cotton Company of Utica moved its equipment to Lafayette, Alabama, the rayon operation was installed in its stead and the initial operation of 1,500,000 pounds of viscose yarn started with the technical advice of experts from France.<sup>20</sup> The following year, 1926, other textile industries, the Amoskeag Manufacturing Company, largest cotton spinners in the country, began to produce 1,500,000 pounds of viscose yarn for its own use at Manchester, New Hampshire.<sup>21</sup> Textile industrialists also backed the Delaware Rayon Corporation which purchased the former shell-loading plant of the Bethlehem Steel Corporation at New Castle, Delaware.<sup>22</sup> An offshoot of this venture, the New Bedford Rayon Company, at New Bedford, Massachusetts, came into production on June 3, 1929,<sup>23</sup> and the Woonsocket Rayon Company started in 1929.<sup>24</sup>

\* These were principally Snia Viscosa, Unione Italiana Fabbrica Viscosa, and Banca Agricola Italiana.

It looked for a time as if a considerable part of our synthetic yarn was to come from textile-backed plants producing for their own use.

In the closing years of the twenties, however, three new rayon producers without textile connections appeared, destined to become big producers. The consequent easing of synthetic yarn supply checked the need of textile firms to produce their own consumption, an idea which was further discouraged by the growing technical complexities of rayon production and the fact that the business was entirely foreign to textile experience and practice.

All these three big new rayon firms had European roots. First in production, midsummer 1928, was the American Glanzstoff Corporation, with a \$37,500,000 \* plant near Elizabethton, Tennessee, close to the Bemberg plant operating the cuprammonium process under the same ownership.<sup>25</sup> Behind this 5,000,000-pound viscose operation were the strongest rayon interests in Germany,† the Vereinigte Glanzstoff Fabriken A.-G. and its cuprammonium ally, J. P. Bemberg A.-G.<sup>26</sup> The American company had a \$7,000,000 capitalization in 7 per cent cumulative preferred stock and 300,000 shares of common of no-par value. The German company guaranteed dividends on the preferred stock which was offered in Amsterdam but not in the New York market until 1931.<sup>27</sup> The president of the American Glanzstoff Company and also of the Bemberg Corporation adjoining, was Dr. Arthur Mothwurf,<sup>28</sup> who also served as president of the newly formed Elizabethton Trust Company. Almost as soon as the first unit was in operation, Glanzstoff made plans for a second plant to double the capacity. This was started in 1929, financed by the sale of 150,000 common shares at \$60 a share.<sup>29</sup>

The second of these large rayon enterprises, the American Enka Corporation, was backed by Dutch know-how, Nederlandsche Kunstzidefabriek, which retained a controlling interest although there was considerable American capital in the corporation.‡ Its operation

\* As reported at the time, though this is a large sum for a plant of this capacity.

† When Dr. Fritz Bluethgen, chmn. bd., Glanzstoff; Dr. Wilhelm Springorum, dir., Glanzstoff; and Dr. Carl Benrath, chmn. bd., Bemberg, visited this country in 1927, they were hailed as the 3 leading artificial fiber experts in the world and it was claimed that their companies combined resources of a billion dollars. [See *Chem Mkts.* 20, 821 (1927).]

‡ The officers were Jacques C. Hartogs of Enka-Maekubee, Arnhem, Holland, pres.; C. McD. Carr, commercial vice-pres.; A. J. L. Moritz, vice-pres. and tech. mgr.; C. Vanderhooven, secy. and asst. treas.; J. T. Johnson, treas.; and Gaylord Davis, asst. secy. Serving on the bd. dir. besides Hartogs was a distinguished group of American executives and financiers: chmn., Frederic W. Allen, Lee, Higginson & Co.; vice-chmn., F. H. Fentener van Vlissingen, Maekubee, Utrecht, Holland; O. L. Alexander, Pocahontas Coal Co.; George H. Burr, Geo. H. Burr & Co.; Franklin d'Olier, Prudential Life Insurance Co.; H. C. McEldowney, Union Trust Co.; P. A. Rockefeller, National City Bank; Philip Stockton, Old Colony Trust Co; Fred L. Seely, Biltmore Industries; and Frank Koenigs, Rodius-Koenigs Trading Corp.

began July 4, 1929, in a plant at Asheville, North Carolina, with a capacity of over 10,000,000 pounds of yarn a year. The company's technical matters were directed by Dutch specialists, while financial and administrative affairs were generally conducted by American executives.<sup>30</sup>

Italian La Soie de Chatillon was the parent of the American Chatillon Corporation which in 1928 started construction of a viscose plant at Rome, Georgia. The American corporation was backed jointly by the Italians and important American textile and financial interests,<sup>31</sup> among whom were Rufus W. Scott of R. W. Scott Hosiery Mills, W. W. McLellan of the McLellan Stores, John W. Mettler of Interwoven Hosiery, Alexander Poss, large textile mill owner, F. A. Powdrell of the Grant dry-goods chain.\* It had a capitalization of \$5,000,000 in \$100 par, with an authorized issue of \$10,000,000 in 7 per cent cumulative preferred stock and 540,000 shares of no-par common.<sup>32</sup> Construction started May 7, 1928, and the new plant was estimated to cost some \$10,000,000 for an initial daily production of 12,000 pounds of viscose and 6,000 pounds of acetate fibers.<sup>33</sup>

By 1930, therefore, viscose rayon plants were spread from New Hampshire to Ohio to Georgia, but already the weight of production began to gravitate toward the South. The new plants of Viscose and du Pont and later that of Industrial Rayon, were all located in Virginia and the three latest big operations, in Tennessee, North Carolina, and Georgia. This southward move, justified by climatic reasons and accessibility to raw materials, was further encouraged by the similar migration of the New England textile industry. Viscose yarn was overwhelmingly the favorite, but rivals began to appear.

Throughout the entire period nitro rayon, based on the original nitro-cellulose process of Chardonnet, was produced by one, and only one, company, the Tubize Artificial Silk Company at Hopewell. This company had been incorporated in Delaware in 1920 and the first fiber was produced in the summer of 1921. Originally financed largely by the Fabrique de Soie Artificielle de Tubize of Belgium, working under patent licenses and technical cooperation upon a royalty basis with the Belgium company, a majority interest was gradually acquired by American stockholders and rights to the patents purchased outright, saving the annual royalty charges.<sup>34</sup> Associated with the management were

\* The officers were Scott, chmn. bd.; Dr. Marco Biroli, vice-chmn. bd.; Dr. D. M. Balsam, pres.; Ugo Mancini, 1st vice-pres.; McLellan, 2d vice-pres.; W. B. Gellard, secy. and asst. treas.; and M. E. Tanham, treas. On the bd. dir. were also Mancini, Gerrish Milliken, Mettler, Poss, Roland L. Taylor, Powdrell, Harry A. Arthur, Gellard, A. R. Balsam, Arthur E. Goddard, S. Fusi, H. S. Davis, Charles C. Lawrence, and L. Liebguth.

several men well known in chemical circles. The president was Walter L. Coursen, who had formerly been general production manager of the New Jersey Zinc Company, while on the board were Edward V. Peters, who as sales manager of New Jersey Zinc had long had an important place in the sulfuric acid market, and John Anderson, chairman of Charles Pfizer & Company. During the 1920's production stepped up from 3,500,000 pounds to over 8,000,000 pounds annually, and although the nitro process attracted no direct competitor, nevertheless the Tubize operation was notably successful, its earnings of \$32 a share in 1925 then being a record for the industry.<sup>35</sup>

On the contrary, acetate and cuprammonium filaments, neither of which was being produced commercially \* at the beginning of the decade, were both coming from the spinnerets by millions of yards daily, from five different plants in 1929. While the outsider was dumbfounded at the dizzy expansion of the rayon industry, insiders were impressed, and disturbed, too, by the appearance and immediate acceptance of fibers from other processes, notably acetate.<sup>36</sup> So impressive was the success of acetate that both Viscose and du Pont, largest producers by the viscose process, had acetate plants in operation by 1930.

The prompt commercial acceptance of acetate rayon was due in a goodly measure to the acumen of Camille Dreyfus. In Switzerland, then in England, and later in this country, he and his brother Henry had been the real pioneers in cellulose acetate.† He did not put his product on the market until both process and quality had been highly perfected and dyes suitable for this distinctive yarn had been developed. Accordingly, it was 1924 before he began converting part of the cellulose acetate film plant at Cumberland, Maryland, to filament operations and 1925 before the first yarn came through the spinnerets.<sup>37</sup> This product is fundamentally different from other rayons in that the acetate

\* Although the Lustron Co., probably the first manufacturer of acetate rayon in the world, did not liquidate till 1927, and the American Cellulose & Chemical Co. had an experimental fiber unit in operation as early as 1920, there was no production that in any realistic sense could be called commercial till 1924. The growth of acetate output was sensational, but statistics are lacking for the early years. An S.F.C. prospectus of the Celanese Corp., filed July 1, 1942, gives the following figures as estimated by the Textile Economics Bureau:

#### U. S. Production of Cellulose Acetate Yarn

Year	Million Pounds	% of Total Rayon	Year	Million Pounds	% of Total Rayon
1925	1.6	3.2	1928	6.0	6.2
1926	2.6	4.2	1929	8.4	7.0
1927	5.1	6.8	1930	9.8	7.7

† See Vol. III, p. 375, also Haynes, *This Chemical Age*, p. 295; H. W. Ambruster, *Rayon* 11 (Dec. 30, 1925); E. P. Partridge, *Ind. Eng. Chem.* 23, 493 (1931); *Fortune* 51, Oct. 1933.

is not a regenerated cellulose, and Dreyfus launched a novel and strikingly successful merchandising campaign. In 1924 the industry had agreed upon the word "rayon" as a generic term for artificial silk,<sup>38</sup> and the term was officially adopted by the National Retail Dry Goods Association and endorsed by the Federal Trade Commission.<sup>39</sup> But Dreyfus shrewdly capitalizing the distinctive character of his fiber, rejected the generic term, trade-named his yarn Celanese, and went out boldly to sell it as a quality product at a price almost twice that of the ordinary viscose yarn.<sup>40</sup>

The year 1927 was packed with signal events for Celanese. The company was now in its stride. Profits the year before had been \$1,458,517, so that, after dividends and taxes, \$338,626 was added to surplus, bringing total assets to \$12,055,866.<sup>41</sup> An addition to the Cumberland, Maryland, plant costing \$8,000,000, of which \$1,000,000 was spent for seven one-story-and-a-half buildings for "chemical service," doubled its capacity to 6,000,000 pounds a year.<sup>42</sup> These tangible evidences of prosperity culminated in adding \$25,000,000 to the capitalization,\* used to acquire control of British Celanese, Ltd., and to buy the Celluloid Corporation.<sup>43</sup> This year also Canadian Celanese, Ltd., a wholly owned subsidiary, completed its plant and in September started the production of yarn from acetate imported from the United States.<sup>44</sup> At this point the name was changed to the Celanese Corporation of America.<sup>45</sup>

The aggressive expansion of Celanese was the best possible propaganda for acetate fiber, especially impressive to its competitors, and late that year the du Pont Rayon Company acquired the manufacturing and sales rights in this country for acetate flake from the Société Chimique Usines du Rhône<sup>46</sup> and shortly afterwards, the cellulose acetate yarn process of the Société Rhodiaceta, taking over from the Rhodia Chemical Company of New York its exclusive sales agency for the sale of cellulose acetate products made by its French parent.<sup>47</sup> A new plant at Waynesboro, Virginia, was immediately started to cost between four and six million dollars. Production began early in 1929 with cellulose acetate yarns, trade-named Acele, and a separate sales division under Frank R. Scull was set up.<sup>48</sup>

Stirred by these developments, Viscose decided to bring to this country the acetate process controlled by Courtaulds.† Like du Pont, once

\* The financing was arranged through J. P. Morgan & Co., with participation by the Bankers Trust Co. and National City Bank and in London by Robert Fleming & Co., the original financial backers of Dreyfus. In Apr. Celanese offered shareholders rights to blocks of 4 shares of 7% pfd. and 1 share of common at \$450 per block, and in the early autumn, the Morgan syndicate sold 250,000 shares of \$100 pfd. and 120,000 shares of new "split" no-par common, exchanged at the rate of 3 for 22 with the holders of the old common. The excess common stock was sold in London by Fleming.

† Courtaulds had not only sponsored the Cross and Bevan development of viscose



the decision to produce acetate fiber was made, plant construction was started immediately, and in 1929 production began at Meadville, Pennsylvania, with a capacity of 5,000,000 pounds yearly. The product was a 76 denier acetate filament sold under the trade name of Seraceta.<sup>49</sup>

In the meantime the American Chatillon Corporation at Rome, Georgia, was making both viscose and acetate rayon which it was marketing under the trade name Chacelon.<sup>50</sup> Its initial daily production of 1,500 pounds was advanced to 2,500 pounds by July and to 7,000 pounds, October 1929.<sup>51</sup> That fall Chatillon and Tubize (which had produced nitrocellulose yarn since 1920 at Hopewell) combined their acetate rayon enterprises on a 50-50 basis in the National Acetate Silk Company,\* incorporated in Delaware with \$10,000,000 preferred stock and 300,000 shares of no-par common.<sup>52</sup> A plant was built near Hopewell using the Chatillon process.

To the four plants at this time producing acetate yarn must also be added four cuprammonium operations.† Only one of these had a large output and one was built upon a frankly experimental basis. The combined output of these in 1929 was about 5,000,000 pounds.<sup>53</sup>

The first American cuprammonium plant in point of time and of production was that of the American Bemberg Corporation. Based on Bemberg patents, endowed with Bemberg technical supervision, backed by Bemberg money, this operation was from the first closely allied with the Glanzstoff company and plant. The American corporation had a capitalization of \$17,500,000. The chairman was Dr. Fritz Bluethgen; the managing director, William Langenbruch; the president, Dr. Arthur Mothwurf; the vice-president and technical director, Max Koeff.<sup>54</sup> Cuprammonium yarn, which had been eclipsed by the early rise and great popularity of viscose, was enjoying a revival among the textile mills, but its truly significant contribution was the introduction into this country of the stretch-spinning process, later to be adapted to viscose yarn, to the perfection of finer, stronger filaments.‡ The cen-

fiber, but also acquired a wide range of patents and patent rights in both the nitro and acetate fields.

\* In 1930 the two firms combined as Tubize-Chatillon, and later changed the name to Tubize.

† First alternative process to Chardonnet's nitro rayon was based on ammoniacal copper oxide as a cellulose solvent developed by Despaisses in 1890, and after his death, perfected by Pauly in Germany. See E. S. Brumberger, *Rayon* 11 (Dec. 15, 1925); for tech. details, L. S. Fryer, *Chem. Met. Eng.* 30, 743 (1924); for description of Elizabethton plant, S. D. Kirkpatrick, *ibid.* 34, 477 (1927).

‡ "I believe it is debatable whether stretch spinning was adapted from the cuprammonium to the viscose process. The term 'centrifugal system' is merely another name for the bucket-spinning system which twists the yarn and winds it into a cake in the single operation. This results from a difference in the speed of the thread going into the bucket and the bucket speed itself. As these relationships are changed the amount of twist in the yarn will vary. This method of spinning and collecting thread was, I believe,

trifugal system had also been applied to the cuprammonium process whereby the winding and twisting of the filaments is completed in a single operation.<sup>55</sup>

Two years previous to the establishment of Bemberg at Elizabethton, the Henry Doherty Silk interests had become interested in the cuprammonium process, organized Cupra, Inc., and enlisted the technical cooperation of the Atlas Powder Company. After a discouraging experimental period, the Napon Rayon Corporation emerged in 1925 with W. J. Webster, president of Atlas as president; W. A. Layfield, also of Atlas, vice-president; George W. Middleton, formerly with the American Raw Silk Company, as secretary-treasurer; and Henry Doherty, chairman of the board.<sup>56</sup> The enterprise was short-lived, but it was soon followed by the Rosland Corporation, a cuprammonium operation backed by Paterson, New Jersey, silk interests.<sup>57</sup>

A third cupra enterprise was that of W. H. Furness who had been experimenting along novel lines with the cuprammonium process.\* In 1927 the Furness Corporation was set up with a capitalization of \$5,000,000 and plans drawn for a \$10,000,000 plant at Gloucester City, New Jersey, to produce 30,000 pounds of yarn daily.<sup>58</sup> Three years later, early in 1930, it was announced that the plant would be in production in July and that Forrest Brothers had been appointed sales agents.<sup>59</sup> But the operation was not successful.†

Increased output and diversification of fiber production was accompanied by improvements in quality and reductions in price. Textile mills noted stronger, finer, more uniform filaments, and the introduction of stretch-spinning and the appearance of low-luster ‡ yarn all lowered the resistance to "synthetic silk." Cut-staple fiber was also introduced, but it achieved only a modicum of its subsequent usefulness and popularity. There were some surprising changes in the uses of rayon. In 1922 the greatest consumer was knit goods, followed in order by hosiery, silk goods, braids, and cotton goods, while in 1927 the order stood women's underwear first, followed by cotton goods, hosiery, silk goods, and knit goods.<sup>60</sup>

Better quality was accompanied by lower prices. The average monthly quotation in New York for 150 denier, grade A, which at the opening of World War I had been \$2.13 and which rose in 1919 to \$4.77, had come down in 1920 to \$2.80. Thereafter price reductions

original with the viscose process and you indicate that it was subsequently applied to the cuprammonium process." (B. M. May, to author, Jan. 29, 1947.)

\* U. S. Pat. 1,770,750 (1930). See also T. R. Olive, *Chem. Met. Eng.* 39, 326 (1932).

† In 1934, after a stockholders' suit, Furness was reorganized as the New Process Corp., which in turn was succeeded by the Imperial Rayon Corp. in 1939.

‡ In 1929 there were three "low-luster" yarns on the market: Discrella of Enka, Dulesco of Viscose, and Lolustra of du Pont. (See *Rayon* 36, Jan. 1, 1929.)

were marked and consecutive: for 1924, \$2.11; 1925, \$2.00; 1926, \$1.81; 1927-28, \$1.49; and 1929, \$1.12.<sup>61</sup>

Reflecting jointly improved techniques, growing output, and insistent pressure upon costs, a significant change in cellulose raw materials came during the twenties in the gradual switch from cotton linters to wood pulp. Only since 1920 had linters—short fuzz stripped from the cotton-seed—wholly replaced rags as a source of cellulose in the Celluloid and viscose fiber plants.<sup>62</sup> Almost immediately research began for a process to separate and purify alpha cellulose from wood pulp.\* A leader in this work was the Brown Company, then the largest producers of forest products in the world. For 60 years under the management of a single family, the enterprise developed in three departments: lumber, pulp and paper, and chemical products.<sup>63</sup> At its Cascade Mill, Berlin, New Hampshire, under the direction of George A. Richter,† a number of different cellulose materials were developed; Alpha Fibre, a high alpha cellulose-containing substitute for rags in papermaking and for cotton linters in rayon, Celluloid, etc.; Duracel Fibre to replace hemp and jute; and Wytek Fibre for paper manufacture. Until 1925 satisfactory alpha cellulose from wood pulp was available from but one or two sources. After this date, however, a number of suppliers appeared and there was an active importation of Norwegian pulp for this purpose.<sup>64</sup> Rayon manufacturers themselves had been experimenting, and in 1925 Viscose, du Pont, and a number of the smaller producers switched more or less of their production to wood pulp cellulose.<sup>65</sup> In 1929 the rayon industry consumed 44,000 tons of wood alpha cellulose against 25,000 tons of cotton linters.<sup>66</sup>

The hunt for a cheaper source of cellulose did not begin and end with wood pulp. At this time the economic distress of the American farmer suggested the salvage of all sorts of agricultural wastes, and the Bureau of Chemistry and Soils through Henry G. Knight‡ and Charles A. Browne,§ its director and assistant chief, publicized the enormous

\* Cotton linters are almost pure alpha cellulose, 98%; the average bleached sulfite wood pulp contains 88-90% alpha cellulose.

† Graduate of Mass. Inst. Tech., 1913, Richter went immediately to Brown and soon rose to dir. research. He was Lt. Col., Chem. Warfare Serv. Reserves, and member of the New England Council.

‡ Past pres. (1932-34) and medalist (1940) of the Am. Inst. Chem., Knight taught chem. and was research dir. at several universities and Exp. Sta. before joining Bur. Chem. in 1927. He was born in Kansas in 1878 and studied at U. Wash. (A.M., 1904) and Chicago (Ph.D., 1917).

§ Browne (1870-1947) was educated at Williams (A.M., 1896) and Göttingen (Ph.D., 1901), becoming head of Bur. Chem. Sugar Lab. in 1906. He was chem. for N. Y. Sugar Trade Lab., 1907-23, before returning to Govt. service. He received the award of the Associate Grocery Mfrs. of Am. in 1935 and was pres., Assoc. Official Agr. Chem. and History of Science Soc. Author of many works, he was an authority on the early history of chem. and alchemy.

quantities of cellulose and lignin available in cornstalks, corncobs, oat and cottonseed hulls, cereal straws, and similar farm by-products.<sup>67</sup> Serious attempts were made to recover the cellulose from two of these wastes.

In 1927 the Massasoit Manufacturing Company, which 30 years before had pioneered in the use of cotton linters and had not lost its interest in waste products, opened a plant for the recovery of cellulose from rice hulls. Two years' experimental work preceded this venture, which was advantageously located in Louisiana, next door to the Lake Charles Rice Milling Company, one of the largest in the world. Some \$200,000 had been invested, and the Louisiana Legislature exempted the plant from certain taxes until a process could be worked out to dispose of what was a serious waste-disposal problem of the rice millers of Louisiana and Texas.<sup>68</sup>

Cellulose from cornstalks also had its commercial trial at this time. Rights to the Dorner process, which was reported to yield 33-35 per cent of 95% alpha cellulose,<sup>69</sup> were controlled in this country by the Euramerican Cellulose Products Corporation, and the Cornstalk Products Company was organized in 1928 with \$750,000 capital, to acquire these and operate a plant at Danville, Illinois, producing alpha cellulose,\* a gum adhesive substitute, and industrial alcohol.<sup>70</sup> The plant came into production during 1928 and shortly thereafter the Cornstalk Products Company bought out its foreign affiliate, took over the patent rights, and started a cornstalk pulp plant at Tilton, Illinois.<sup>71</sup> Direct evidence that usable pulp could be produced was the printing in 1928 of the *Commercial News*, Danville daily paper, the *Prairie Farmer*, and the book, *Farm Products in Industry*, by George M. Rommci, on paper † made from it by the Kalamazoo Vegetable Parchment Company and the Michigan Paper Company.<sup>72</sup> Although something like \$1,500,000 was spent on this waste-utilization attempt, the Cornstalk Products Company was not a success. Its failure was due not so much to the process or the product, as to the economic difficulties of collecting sufficient raw material to maintain a profitable, year-round operation, aggravated by the high costs of cleaning that raw material of dirt and other foreign matter.

\* Cornstalks as a source of cellulose for papermaking had been proposed in 1838 by Homer Holland who was granted U. S. Pat. 878 for his process, and up to 1927 some 25 similar U. S. Pats. had been granted. For excellent tech. description of the Danville plant, see H. A. Webber, *Ind. Eng. Chem.* 21, 270 (1929).

† It is interesting to note that 18 yrs. afterwards this paper, in a copy of the book in my library, is still in excellent physical condition. It has yellowed very slightly, but my recollection is that even when first received the text stock was not "dead white," and there is apparently no change in the coated stock used for the illustrated pages. (W. H.)

As Dr. Howe had pointed out, cellulose had in truth become an exceedingly important chemical raw material, and this interest in its chemical characteristics and industrial applications was recognized as early as 1923 when a group of cellulose chemists, temporarily organized, became a permanent Cellulose Division of the American Chemical Society.<sup>73</sup> In 1927 the full-fledged industrial status of synthetic fibers was testified by the organization of the Rayon Institute which in 1929 was succeeded by the Rayon and Synthetic Yarn Association<sup>74</sup> with a membership of 14 American manufacturers.\* The first president elected was Samuel A. Salvage, president of Viscose, and the vice-president, Leonard A. Yerkes of du Pont. William C. Matthews was counsel for the association and acted as secretary, and the executive committee consisted of R. S. Fuller, Jr., chairman of the American Glanzstoff Corporation; Hiram Rivitz, president of Industrial Rayon; J. P. Wright, president of New Bedford Rayon and Delaware Rayon; and B. G. Slaughter, president of the Tubize Artificial Silk Company. That same concern for the quality of all types of rayon which disturbed Courtauld, was one of the chief activities of this new trade association. Its earliest committees were charged with setting up standards for yarn and specifications covering spun rayon.

\* These manufacturers were: Acme Rayon Corp., American Bemberg Corp., American Chatillon Corp., American Enka Corp., American Glanzstoff Corp., Belamose Corp., Delaware Rayon Corp., du Pont Rayon Co., Industrial Rayon Corp., A. M. Johnson Rayon Mills, New Bedford Rayon Co., Skenandoa Rayon Corp., Tubize Artificial Silk Co. of America, and Viscose Co.

#### REFERENCES

1. Quoted in *Chem. Mkts.* 20, 631 (1927).
2. Avram, *Rayon Industry*, p. 51; *Chem. Mkts.* 25, 80 (1929).
3. *Chem. Mkts.* 21, 854 (1927).
4. *Ibid.* 23, 583 (1928); *Rayon & Synth. Yarn J.* 39 (July 1931).
5. *Chem. Met. Eng.* 34, 586 (1927).
6. *Drug Chem. Mkts.* 17, 156, 1537 (1925); *Rayon & Synth. Yarn J.* 22 (July 1931), 36 (Aug. 1933); figs. corrected by F. Bonnet, to author, Jan. 20, 1947.
7. *Rayon & Synth. Yarn J.* 36 (Aug. 1933).
8. *Drug Chem. Mkts.* 13, 487, 530 (1923).
9. *Chem. Met. Eng.* 34, 646, 656 (1927), 35, 264 (1928); *Chem. Mkts.* 21, 456 (1927), 22, 419 (1927), 23, 583 (1928); *Rayon* 36 (Jan. 1, 1929), 47 (June 15, 1929).
10. *Chem. Mkts.* 21, 160 (1927); *Chem. Met. Eng.* 34, 528, 592 (1927); *Rayon & Synth. Yarn J.* 36 (Jan. 1, 1929).
11. *Rayon* 36 (Jan. 1, 1929).
12. Avram, *op. cit.* p. 56; *Ind. Eng. Chem., News Ed.* 12, 274 (1934).
13. Avram, *op. cit.* p. 149.
14. *Drug Chem. Mkts.* 17, 355 (1925).
15. *Ibid.* 18, 21 (1926).
16. Avram, *op. cit.* p. 149.
17. *Rayon* 50 (Jan. 1, 1930).
18. Avram, *op. cit.* p. 57.
19. *Ibid.*
20. *Ibid.* p. 58; *Drug Chem. Mkts.* 17, 914 (1925).
21. Avram, *op. cit.* p. 58; *Rayon & Synth. Yarn J.* 42 (July 1931).
22. Avram, *op. cit.* p. 57.
23. *Rayon* 59 (Jan. 1, 1930).
24. *Rayon & Synth. Yarn J.* 35 (July 1931); *Chem. Mkts.* 23, 583 (1928); *Chem. Met. Eng.* 35, 264 (1928).
25. *Chem. Met. Eng.* 34, 385, 720 (1927).

26. L. Domeratzky, Bur. For. Dom. Com., *Trade Inform. Bull. No. 556*, 55 (1928).
27. *Chem. Met. Eng.* 34, 385 (1927).
28. *Chem. Mkts.* 21, 366 (1927).
29. *Rayon* 29 (Sept. 15, 1928); 25 (Jan. 1, 1929); 59 (Jan. 1, 1930).
30. Avram, *op. cit.* p. 60; *Chem. Met. Eng.* 35, 318 (1928); *Rayon* 8, 28 (May 15, 1928); *Moody's Manual of Investments, Industrials, 1930*, p. 2313.
31. *Rayon* 27 (June 1, 1928), 36 (June 1, 1929); *Chem. Mkts.* 22, 645 (1928).
32. *Rayon* 42 (June 15, 1929).
33. *Ibid.* 8 (May 15, 1928); 35 (June 15, 1929).
34. Avram, *op. cit.* p. 146.
35. *Ibid.*, p. 147.
36. C. E. Mullin, *Ind. Eng. Chem.* 22, 461 (1930); *Plastics* 7, 143 (1931).
37. Co. memo to author.
38. *Drug Chem. Mkts.* 14, 1330 (1924); 16, 883 (1925).
39. *Ind. Eng. Chem., News Ed.* 2 (Nov. 20, 1925).
40. Haynes, *This Chemical Age*, p. 295.
41. *Chem. Mkts.* 20, 451 (1927).
42. *Ibid.* 941; *Rayon* 33 (June 15, 1928).
43. Co. memo to author; *Chem. Mkts.* 20, 511, 961, 968 (1927), 21, 162, 299 (1927).
44. *Chem. Mkts.* 20, 461 (1927).
45. *O.P.D. Reprtr.* 38B (May 2, 1927).
46. Co. memo to author; *Rayon J.* 35 (Dec. 1927).
47. *Chem. Mkts.* 23, 162 (1928); *Rayon* 10 (July 15, 1928), 29 (Sept. 15, 1928), 39 (Nov. 1, 1928).
48. *Ind. Eng. Chem., News Ed.* 16 (Nov. 20, 1929).
49. *Rayon* 38 (Apr. 15, 1929); 28, 59 (Jan. 1, 1930).
50. *Ibid.* 42 (June 15, 1929).
51. *Ibid.* 35, 46 (June 15, 1929).
52. *Ibid.* 35 (June 1, 1929), 32 (July 15, 1929); *Chem. Mkts.* 25, 179 (1929).
53. *Chem. Mkts.* 23, 585 (1928).
54. S. D. Kirkpatrick, *Chem. Met. Eng.* 34, 477 (1927); *Drug Chem. Mkts.* 17, 225 (1925).
55. Hard, *Romance of Rayon*, p. 45.
56. E. Wunderlich, *Rayon* 30 (Nov. 30, 1925).
57. Avram, *op. cit.* p. 59.
58. *Rayon* 25 (July 30, 1927); *Chem. Met. Eng.* 34, 528 (1927).
59. *Rayon* 45 (May 1, 1930).
60. Avram, *op. cit.* p. 257.
61. *Ibid.* p. 249; note the average for 9 mos., 1929, is incorrectly stated as \$1.96.
62. L. W. Bass and H. S. Olcott, *Ind. Eng. Chem., News Ed.* 18, 141 (1940).
63. G. A. Richter, *Ind. Eng. Chem.* 22, 194 (1930).
64. F. D. Snell, *Rayon* 9 (Oct. 27, 1925).
65. J. Hyde, *ibid.* 17 (Sept. 14, 1925).
66. Haynes, *op. cit.* p. 273.
67. *Ind. Eng. Chem.* 20, 226, 882 (1928).
68. *Ibid.* 19, 20 (1927); *Chem. Met. Eng.* 34, 188 (1927); *Chem. Mkts.* 20, 364 (1927).
69. D. H. Killeffer, *Ind. Eng. Chem.* 19, 1080 (1927).
70. *O.P.D. Reprtr.* 24 (Mar. 19, 1928); *Ind. Eng. Chem., News Ed.* 2 (May 20, 1928); *Chem. Mkts.* 22, 421 (1928).
71. *Chem. Mkts.* 25, 77 (1929); Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Co. brief, Mar. 11, 1929, p. 9985.
72. *Chem. Mkts.* 23, 161 (1928); 24, 32 (1929).
73. *Ind. Eng. Chem., News Ed.* 3 (Feb. 10, 1923).
74. B. M. May, to author, Jan. 29, 1947; *Rayon* 7 (Nov. 15, 1929).

## Chapter 24

### PETROLEUM AND TETRAETHYL LEAD

THERMAL CRACKING BECOMES STANDARD REFINERY PRACTICE—ROCKEFELLER AND UNIVERSAL OIL SUBSIDIZE FUNDAMENTAL RESEARCH—CHEMICAL INTEREST ENCOURAGED BY CATALYTIC CRACKING, HYDROGENATION, SOLVENT DEWAXING—CHEMICALS FROM GAS AND OIL DEVELOPED BY CARBIDE AND CARBON, AND SHARPLES—GENERAL MOTORS PERFECTS TETRAETHYL LEAD ANTI-KNOCK ADDITIVE—ADVANCES IN NATURAL GASOLINE TECHNIQUE—"BOTTLED GAS" GROWS RAPIDLY.

THE AMERICAN PETROLEUM INDUSTRY had reached the point by 1926 where it was resentfully self-conscious of criticism of its chemical lethargy. Two years before, at the behest of Van H. Manning, Benjamin T. Brooks prepared for the American Petroleum Institute a report on petroleum research, advocating that a series of fundamental studies in petroleum chemistry be undertaken cooperatively. Written in the hope of thus avoiding company jealousies and competition with industrial projects, this strong plea for a research subsidy, though endorsed by a committee consisting of Wilder D. Bancroft, James F. Norris, Hugh Taylor, George Burrell, Charles H. Herty, and Dr. Brooks, was dutifully filed and nothing happened.

At the 1926 meeting of the American Chemical Society, Dr. Charles H. Herty, who was always scanning the chemical horizons, took the neglected chemical possibilities of petroleum as the text of a speech. Neatly mixing wit and sarcasm, he charged that the oil companies did no research unless it had a direct bearing upon their own production problems. The petroleum chemists rose angrily in their own defense, and in the controversy someone drew that report out of the files, dusted it off, and a great many people read it for the first time.<sup>1</sup>

Shortly thereafter John D. Rockefeller gave \$50,000 a year for the next five years, to be administered by Walter C. Teagle, J. C. Donnell, and R. L. Welch, for fundamental research in petroleum. Almost immediately Hiram J. Halle, president of the Universal Oil Products Company, announced that his company would donate a similar sum under similar conditions for the same purpose.

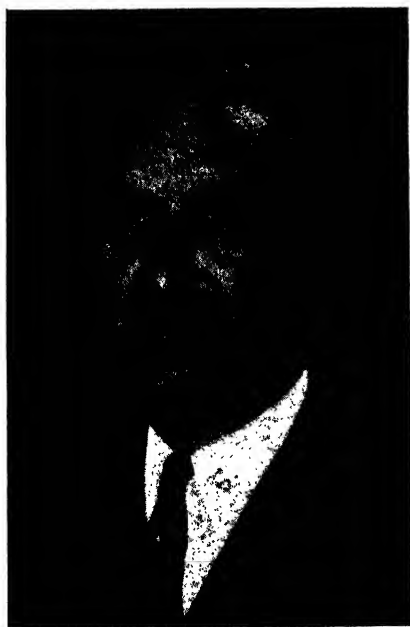
This goodly sum was more than a mere token of chemical interest. The American Petroleum Institute entrusted this fund to the National Research Council which set up an administrative committee consisting of James F. Norris, Hugh Taylor, Robert Milliken, B. T. Brooks, K. C.



ROBERT P. RUSSELL



R. T. HASLAM



FRANK A. HOWARD



WILLIAM M. BURTON





*Oil, Paint & Drug Reporter*

**CHARLES F. KETTERING**



*Chemical & Engineering News*

**THOMAS A. BOYD**



*Oil, Paint & Drug Reporter*

**GRAHAM EDGAR**



*Chemical & Metallurgical Engineering*

**THOMAS MIDGLEY, JR.**

Heald, and E. W. Washburn. The first project was a study of the means of identifying sulfur compounds in crude oil and its products, conducted at Johns Hopkins under Dr. Parry Borgstrom.<sup>2</sup> Later, when such researches had proved themselves harmless to the industry and interesting, the Petroleum Institute took over direct administration of this \$100,000 fund.

The decade 1920-30 saw a technical renaissance in the petroleum industry. It was the great period of thermal cracking when there was much development of new processes and improved techniques that superseded the original Burton process. These new methods made money and unprecedented sums were paid out in patent royalties. Moreover, cracking operations brought a great number of engineers into the industry, and as new chemical processes began to appear—notably catalytic cracking, gasoline antioxidants, and solvent extraction of lubricating oils—the number of chemists employed also began to increase.

Nevertheless most of this chemical activity was pretty strictly confined to wringing the last drop of motor fuel out of gas and oil, of lowering refining costs, and of raising the quality of gasoline, lubricants, and fuel oil. The strictly chemical developments took place outside the petroleum industry, but they did influence its thinking to an extent that petroleum men in offices, plants, and laboratories came by 1930 to be definitely chemically minded.\* Tetraethyl lead, perfected by General Motors and produced by du Pont, not only improved the performance of gasoline, but it focused attention upon the chemical constitution of

\* "Many examples might be given to illustrate how great the change was in this thinking. After the production of cracked gasoline had become important, the customary, nearly universal method of chemical refining was applied to it, namely treatment with concentrated sulfuric acid. Practically nothing was known about the chemistry of what happened in acid refining. The acid sludge was diluted with water and boiled to separate what was called 'acid oil' before reconcentrating the acid. This acid oil had a strong and somewhat camphoraceous odor, thought by some to be ketones formed in some way. In 1918 I published the results of a research, together with I. W. Humphrey, and showed that these acid oils consisted of olefin polymers and that the fragrant constituents were higher alcohols, secondary and tertiary. However, the industry continued to refine cracked gasoline with large proportions of sulfuric acid for another five or six years before it was realized that the loss by the formation of heavy polymers, which were lost on redistillation, was several times the observed loss on treating with acid. The distillation methods used in the industry up to about 1925 were so crude that these polymer losses of 3 per cent to 7 or 8 per cent went unnoticed. During this decade all this was quickly changed, sulfuric acid treatment of gasoline was eventually almost entirely eliminated, antioxidants discovered, and high anti-knock values began to be appreciated. One other little fact which illustrates how far we have come was that for many years gasoline had been sweetened as to odor by treating with alkaline plumbite ('doctor solution'). Hundreds of millions of barrels of gasoline had been so treated, but nobody knew what happened in the process until Gerald Wendt showed what happened chemically, in the early 1920's." (B. T. Brooks, to author, Feb. 20, 1947.)

the oil refiners' most important product. Aliphatic chemicals, exploited successfully by Carbide and Carbon and by Sharples, was a demonstration which could not escape the attention of petroleum executives.

As its techniques became more and more chemical, the petroleum industry in spite of itself became a chemical industry. But nearly a score of years passed before Dr. Herty's pithy criticism was nullified by any widespread, serious interest in chemical products from the petroleum hydrocarbons. There were exceptions, of course, but for the industry as a whole, the 1920's were years when the chemicalization of refinery processes was most successfully adopted with but scant attention to the broader chemical implications.\*

Once started, the evolution from physical to chemical technology was rapid.† It was accelerated by numerous discoveries applied in various departments. The industrial milieu was highly favorable between 1916 and 1927, for this was the period of the industry's most vigorous expansion. During these years the quantity of crude oil refined increased 200 per cent, while in response to the growing number of automobiles, the gasoline produced increased 575 per cent.<sup>3</sup>

The year 1926 has been designated by petroleum historians<sup>4</sup> as the date when the cracking process achieved universal recognition. Commercially initiated ‡ at the Whiting refinery of Standard Oil of Indiana

\* "I believe you are far too harsh on the oil industry. . . . I believe the oil industry has been alert to the production of chemicals from petroleum long before 1926. . . . It has gone into the chemical business as rapidly as the economics of the period justified and not before. Standard Oil of New Jersey was producing chemicals for years and worked with Carleton Ellis. Cities Service in 1918, to my knowledge, was producing alcohols at its refinery in Okmulgee, with Prof. Sidney Born of the University of Tulsa in charge. (Born had been working about 1916 on cracked gases from petroleum for a company.) At Tallant it was producing and is still producing methanol, formaldehyde, etc. Shell has step by step added new chemicals to its list, as have other companies, economics justifying. The oil industry in my opinion could drown the chemical industry in chemicals based upon its raw materials and wreck the whole economic picture." (G. Egloff, to author, Feb. 13, 1947.)

With Dr. Egloff's conclusion I heartily concur. In itemizing the chemical activities of the few chemically minded petroleum companies (dealt with in this and the preceding volume—see Vol. III, p. 147), he emphasizes, so it seems to me, the fact that the industry as a whole was distinctly uninterested in chemicals from petroleum hydrocarbons till the World War II period. For a further discussion of these developments, see my *Southern Horizons*, Chap. 13. (W. H.)

† Since we are interested in the chemical aspects of petroleum, I shall not even sketch the phenomenal growth of the industry or the fortunes of the individual companies during this period. All this is capably recorded in the monumental *Science of Petroleum*, particularly in the chapters by Walter Miller and H. G. Osborn, II, p. 1466, and B. T. Brooks, III, p. 2078. (W. H.)

‡ The first American cracking patent (U. S. 28,246) was granted in 1860 to L. Atwood, for a method of increasing the yield of illuminating oils by a cracking distillation at atmospheric pressure. Three years later Brit. Pat. 3,345 was issued to J. Young for cracking shale oils at a pressure of 20 lb. per sq. in. Relatively high pressure and temperature—500 lb. and 700-1,000° F.—were mentioned in L. Benton's U. S. Pats. 342,-

in 1913, by Dr. William M. Burton,\* it was 1936 before the output of "cracked gas" became greater in total volume than that of "straight run." By 1926 there were 26 cracking processes in commercial operation, and 28 more in experimental or demonstration pilot plants, while over 2,500 cracking process patents had been issued.<sup>5</sup> That year the *Oil & Gas Journal* admitted that gasoline from the cracking process was better than the straight distillation product.<sup>6</sup>

Burton's epochal discovery was early modified, first by the false bottom devised by Dr. Robert E. Humphreys; then by the tube pressure still invented by E. M. Clark; and later by tubular stills introduced by Jesse A. Dubbs to break the water emulsion of the Pacific Coast crudes (U. S. Pat. 1,123,502, 1915), and subsequently adopted to cracking<sup>7</sup> by his son, Carbon Petroleum Dubbs,† and commercially introduced by the Universal Oil Products, a research-patent licensing corporation organized by Hiram J. Halle and financed by J. Ogden Armour. Other cracking processes that made early history were the Cross, developed by the brothers, Walter M. and Roy Cross of Kansas City; the Holmes-Manley, named for R. C. Holmes, president of the Texas Company, and F. T. Manley, its refinery manager; the invention of Carleton Ellis, known as the tube-and-tank process of the Standard Oil Company of New Jersey; Sinclair Refining's Isom method, devised by Edward W. Isom; the Fleming process of Richard Fleming, used in the Maryland refinery at Ponca City, Oklahoma.<sup>8</sup>

Vapor-phase cracking had also appeared, pioneering work having been done ten years before at the Bureau of Mines by Dr. Walter F. Rittman, whose toluene-from-petroleum process had created a stir dur-

564-5 (1886). In 1890, J. Dewar and B. Redwood were granted U. S. Pats. 419,931 and 426,173, covering both vaporization and condensation under high pressure. Though these last two figured in subsequent litigation, all the early patents were unworked because there was no demand for the product they produced.

\* Burton, who was born in Cleveland in 1865, started with Standard Oil (Ind.) in 1890, a yr. after getting his Ph.D. at Johns Hopkins (A.B., West. Reserve, 1886). He rapidly rose to gen. supt., 1895; vice-pres., 1915; pres., 1918. He had started experimental work on cracking crudes in 1910, the first battery of 12 stills going into operation in Jan. 1913. By 1927, 880 Burton stills were working and from 1913-28 more than 200,000,000 bbl. gasoline had been produced. In recognition of his revolutionizing invention (U. S. Pat. 1,049,667), Burton received the Gibbs medal in 1918, the Perkin in 1921. He resigned from Standard Oil in 1927, but remained active as advisor.

† Following in the footsteps of his pioneering grandfather and father, Dubbs has given all his energies to the chemical refining and cracking of petroleum. His cracking process has world-wide use and is owned by the Universal Oil Products Co. of which he became vice-pres. in 1913, when it was organized. The 7 basic patents underlying his work are U. S. 1,231,509 (1917); 1,392,629 (1921); 1,440,772 (1923); 1,488,325 (1924); 1,525,281, 1,534,927, 1,543,831 (1925). Dubbs was born in Franklin, Pa., June 24, 1881, and studied at U. W. Pa. and Phila. Coll. Pharm. In 1901, as asst. supt. of an asphalt plant in Calif., he cooperated with his father in research. He received the John Scott medal in 1929.

ing World War I. Leaders in the vapor-phase method were the "Gyro" process of the Pure Oil Company, the Gulf-Texas process, and the Leamon process.<sup>9</sup> In 1927 Texas and Gulf pooled their efforts and built a new type of low-pressure unit at Bayonne, New Jersey, under the direction of Luis de Florez, who himself made important contributions to the cracking process.<sup>10</sup>

Thomas T. Gray's discovery of fuller's earth as a purifying agent in vapor-phase cracking was patented in 1920 \* and brought into commercial operation at the refinery of the Barnsdall Company at Barnsdall, Oklahoma, in 1924.<sup>11</sup> About the same time the Davison Chemical Company was advocating silica gel for the same purpose.<sup>12</sup> These methods foreshadowed the decline of sulfuric acid as the great, common refining agent of the petroleum industry, and they were soon followed by oxidation inhibitors in cracked gas, *p*-benzylaminophenol, *p*-butylaminophenol, and  $\alpha$ -naphthol.<sup>13</sup> The Gulf Refining Company was already successfully operating the aluminum chloride process developed by A. M. McAfee.<sup>†</sup>

The Edeleanu solvent extraction process<sup>14</sup> based on liquid sulfur dioxide, discovered by Dr. Edeleanu in Rumania before World War I, was at this time applied to California crudes, and the hypochlorite treatment of sweetening gasoline from natural gas, discovered by A. E. Dunstan, chief chemist of the Anglo-Persian Oil Company in England, had been brought to this country by the Mathieson Alkali Works which controlled the patents. It is interesting now to note that these chemical processes were not welcomed warmly.

In 1924, according to Miller and Osborn, "the bubble tower may be said to have reached at least general toleration, if not acceptance"—rather tardy acceptance of an idea that Herman Frasch tried to introduce to the Standard Oil Company in 1898. Very definite progress in the development of more efficient distilling equipment appeared when Dr. W. K. Lewis designed the first commercial plate towers and multiple-stream vacuum flash distillation equipment for Standard Oil Development, which put it in operation at the Bayway refinery in 1922; when the Atlantic Refining Company built a commercial-sized multiple-stream installation in units, each capable of handling 5,000 barrels a day, in 1926; and shortly afterwards when a 7,500-barrel unit was installed by Foster-Wheeler Corporation for the Continental Oil Company at Ponca City, Oklahoma.<sup>15</sup> Clearly, chemical apparatus and chemical reagents were steadily increasing their influence upon petroleum technology and during the closing years of this decade, an entirely

\* U. S. Pat. 1,340,889.

† See Chap. 9.

new chemical process, hydrogenation, markedly raised the prestige of these new chemical methods.

In December 1922, Dr. Friedrich Bergius, at Birmingham University in England, first told the English-speaking world of his proposal to transform coal into a liquid fuel by means of hydrogen.\* His process was greeted by petroleum men with the same skepticism with which American chemists had welcomed the announcement a dozen years before that nitrogen could be extracted from the atmosphere by the use of unheard-of temperatures and pressures.<sup>16</sup> Five years later, when the Standard Oil Company of New Jersey announced that it had acquired American rights to this same Bergius process, everyone concluded that although gasoline was at that time overproduced, this petroleum-refining company was anticipating long in advance the depletion of our oil reserves and was arming itself with a liquid fuel for the internal combustion engine. Both of these snap judgments were quite erroneous. The Bergius process worked, but it was obviously uneconomic to work it in this country on coal, to produce liquid fuels. The Standard Oil Company applied it to petroleum, thus opening an entirely new phase in the chemical treatment of crude oil.

In Germany where the lack of petroleum could never be forgotten, Bergius' idea was embraced eagerly and his patent rights grabbed by that mad industrial genius from the Ruhr, Hugo Stinnes. When his bloated, disjointed Stinnes-Rhein-Elbe-Schuckert-Union collapsed in 1925, the I.G. pulled the Bergius patents out of the wreckage and soon afterwards the Standard Oil Company of New Jersey began negotiating for their American rights.<sup>17</sup> These patents had been vested in a holding company, the International Bergin Company of The Hague, in which the German Chemical Trust was associated with the Ruhr coal and iron industries. The I.G. in Germany, the Royal Dutch Shell in Holland, the Schneider-Creuzot in France, and later Imperial Chemical Industries in England, were all licensees of The Hague concern, and in 1927 Standard Oil (New Jersey), through its Development Company, obtained American rights and entered into a further research exchange program with the I.G. for commercial development of the hydrogenation process. As Walter C. Teagle, Standard Oil's president, pointed out,<sup>18</sup> the arrangements with I.G. did not provide for American financing of a German coal hydrogenation plant in this country, nor did it embrace any agreement as to tetraethyl lead, nor did the du Pont Company have any part in the proposed undertaking which was concerned directly and solely with the technical development of the hydrogenation process. Two years later, after this experimental work had materialized,

\* For review of literature on hydrogenation and liquefaction of coal, see H. H. Storch and others, *Bur. Mines, Tech. Paper No. 622* (1941).

a supplementary agreement was entered into regarding these patents and research, and quite independent of the American I.G. Corporation, the Standard-I.G. Company\* was set up to take over the control of these patent interests.<sup>19</sup>

Meanwhile, the Standard Oil Development Company, of which E. M. Clark was then president, tackled the practical problem of simplifying the hydrogenation process and broadening its applications. A laboratory was set up at the Baton Rouge plant of Standard Oil of Louisiana, equipped first with a model, half-barrel-a-day pilot plant, following the general design of the big I.G. units in Germany.<sup>20</sup> A technical staff was recruited, among whom were W. C. Asbury, Marion W. Boyer, later manager of the Baton Rouge plant, P. J. Byrne, Jr., G. H. B. Davis, W. V. Hanks, and J. M. Jennings, under the direction of two former Massachusetts Institute of Technology professors, Robert T. Haslam † and Robert P. Russell. ‡ In one of the most costly chemical developments ever undertaken, these men thoroughly explored the high-pressure hydrogenation of crude oil. By altering catalysts and modifying operating conditions, the degree of hydrogenation could be controlled and the products varied, researches that eventually led to polymerization of isoöctane and alkylation, which were to be of great value and interest in the petroleum field during the next decade.<sup>21</sup>

While these experiments were exploring the possibilities of chemically modifying petroleum hydrocarbons, a research supported by an automobile manufacturer made definite chemical contributions to improved gasoline. But tetraethyl lead, the prize won by this long search for an anti-knocking agent on the part of General Motors, was not solely a successful motor fuel additive. It served also as a powerful mental catalytic agent, stimulating physical and chemical inquiries into the internal combustion engine and its fuel.

The long hunt that ended triumphantly in "Ethyl" gas § started in

\* Officers: F. A. Howard, pres.; E. M. Clark, vice-pres.; M. H. Eames, secy.; R. P. Resor, treas. Directors: Howard, Clark, W. Duisberg, R. T. Haslam, P. Hurll, H. A. Riedemann, H. G. Seidel, S. A. Straw, Otto v. Schrenk, and G. Wellman.

† Haslam, born in North Adams, Mass., 1888, was trained at Mass. Inst. Tech., B.S., 1911, and returned to his Alma Mater in 1920 after 6 yrs. with the National Carbon Co. When he became vice-pres. and mgr. of Standard Oil Development, he was dir. of the Sch. Chem. Eng. Practice and Research Lab. Appl. Chem. In 1935 he became pres., Hydro Engineering & Chemical Co., in 1946 vice-pres., Standard Oil (N. J.).

‡ Russell earned an A.B. at Clark U. before getting his M.S. at Mass. Inst. Tech., 1922, where he began as a research assoc. in the Lab. Appl. Chem. He was dir., eng. investigations, when in 1927 he went to the Standard Oil (La.). In 1929 he became gen. mgr., Hydro Engineering & Chemical Co.; in 1930 mgr., Development Div., Standard Oil Development, its executive vice-pres. in 1937, and pres. in 1944. He received the Cadman memorial medal in 1947, from the Inst. Petroleum, London.

§ Original sources on the tetraethyl lead researches, two unpublished MSS, *Report* by T. A. Boyd and *A Romance of Research* by Jas. D. Carpenter, in the files of

1916. Because storage of gasoline in residential buildings was forbidden by many state and municipal fire regulations, the sale of Delco household lighting units was barred in many localities, and its inventor, Charles F. Kettering,\* had adapted the engine to run on kerosene instead of gasoline. This was accomplished without any serious difficulties; but in doing so he ran into the obstacle of knock, a trouble which he had experienced earlier in his work on automobile engines. So he asked Thomas Midgley, Jr., a mechanical engineer then working on battery hydrometers in the Delco-Light engineering department, to take an engine indicator which Kettering had previously used for studying the knock in automobile engines and see if the real cause of knock could be found, and also whether a remedy for it might not be provided. The indicator was installed on one of the single-cylinder Delco-Light engines and soon showed that knock was not due to preignition, as had been supposed. In trying to supply a working hypothesis, Kettering suggested that if the fuel were dyed red it might absorb enough more radiant heat to make it vaporize more completely and so burn smoothly and without knock. Midgley proceeded at once to test that idea. No red dyes having been available there at the time, Fred L. Chase suggested that they use iodine to color the fuel red. They did that and found that it stopped the knock completely. They soon discovered, however, that it was not the color but the iodine itself that had stopped the knock. Thus the first of the anti-knock agents, iodine, was discovered.<sup>22</sup>

Meanwhile Kettering had set up a separate research laboratory to study such problems and had engaged as director Frank Orville Clements, his old chemistry teacher at Ohio State University.

We were at war with Germany and better aviation gasoline was a pressing need, so the little staff at Dayton joined in cooperative research with the Bureau of Mines.† Dr. Alan R. Albright, of the Dayton staff

General Motors Corp., have been drawn upon heavily, and I am indebted to Chas. F. Kettering and E. V. Rippingille for having placed this valuable, confidential material at my disposal. See also H. S. Tegner, *Petroleum Times* 19, 750 (1928). (W. H.)

\* Prolific inventor and fruitful inspirer of research, Kettering has received many honors: D.Sc. from U. Cincinnati, Brown, Toledo, Northwestern, Lafayette, N. Y. U., Dartmouth, and Harvard; D.Eng. from Ohio State, Michigan, Brooklyn Polytech. Inst., Detroit U., and Nebraska; medals from Franklin Inst., Ohio State, Cincinnati U., Am. Philos. Soc., the Four Founders Eng. Soc., Western Soc. Engrs., Coll. of La., the Am. Club of Paris, and has been decorated by the French and Belgian Govts. He invented the first practical self-starter for automobiles and the Delco-Light for cars and houses, and has been for many yrs. gen. mgr., Research Div., and vice-pres. and dir. of General Motors. He was born in Loudonville, O., and educated at Ohio State (M.E. in E.E., 1904).

† Assisting from the Bureau were E. W. Dean, now with Standard Oil Development Co.; Chester Naramore, now exec. secy., Petroleum Div., Am. Inst. Min. Met. Engrs.; Clarence Netzen; and John P. Smootz.



and later with Best Foods, Inc., added trinitrotoluene to gasoline—the first of many, many chemicals tried and tested in a one-cylinder Liberty motor. Henry Ford's Knockknocker—a yellow, unsaturated hydrocarbon—was found to be “pretty good,” and the anti-knock value of benzene was determined as well as its handicap for aviation fuel because of its high freezing point, 40° F. From the front lines a cable reported that captured German gas contained cyclohexane. This news kept Midgley, Albright, Netzen, and Smootz at work all night attempting to hydrogenate benzene to produce cyclohexane. On October 26, 1917, using nickel oxide as a catalyst, a yield of 23 per cent was obtained,\* tested most successfully, and it was determined that while the freezing point of cyclohexane was 40° F., a mixture of 80 per cent cyclohexane and 20 per cent benzene had a freezing point of -40°. This mixture was christened Hecter, and by July 50 gallons had been produced in a pilot plant under the direction of T. A. Boyd.† Flying tests resulted in changing the ratio to 70 cyclohexane and 30 benzene.<sup>23</sup> Hecter made it possible to increase the compression of the aviation engine from 5.5:1 to 8:1, and plans were drawn for a plant to produce 300 gallons a day at an estimated cost of from 40–50 cents a gallon, which the end of the war canceled.

During the war comparative tests on the anti-knock properties of ethyl ether and normal butyl alcohol—both  $C_4H_{10}O$ —indicated plainly that knocking could be stopped and suggested work on the structure by hydrocarbons.<sup>24</sup> So the hunt started again in December 1918. Using the good old “Edisonian” method of cut-and-try, literally hundreds of chemicals were tested,<sup>25</sup> among them such diverse compositions as camphor, ethyl acetate, cresol, ethyl chloride, aluminum chloride. Most of these had no effect on fuel performance. Others had some anti-knock value and some actually increased knocking. Hydrogen peroxide had the distinction of being the first positive knock-promoter discovered and zinc ethyl the first metallic alkyl tested. On January 30, 1919, it was found that aniline was an excellent anti-knock, two cubic centimeters being as effective as one gram of iodine. This was a timely strike, for Boyd had tested every chemical on the laboratory shelf and Midgley had issued the ultimatum that the turn of the year “this wild-goose chase will be given up.” In the meantime Midgley ‡ had perfected and pat-

\* Leo Baekeland had skeptically offered a wooden medal for the first pint of cyclohexane and a liter bottle in a plush-lined mahogany case was shipped to him together with a suggested design—a six-sided ring shield surrounded by six very rampant cats, symbolic of their catalyst difficulties—for his proffered award.

† Boyd had just graduated from Ohio State with a B.Ch.E. When the Dayton Lab. was taken over by General Motors, he continued and has for many yrs. been head of the motor fuel researches. He is the author of popular books on gasoline and research.

‡ Midgley (1889–1944) not only headed the tetraethyl lead researches, but was later to discover the organic fluorine refrigerant, Freon. He won not only the Longstreth

ented \* his indicator for which he was awarded the Longstreth medal.<sup>26</sup>

The cut-and-try method was continued. During the summer, college professors were called in as consultants, and Dr. William McPherson and C. E. Boord of Ohio State brought some 70 compounds, while Dr. W. C. Ebaugh of Denison University brought, among others, diphenylamine, which proved to have some anti-knock advantages. That summer, too, the cooperation of du Pont was sought and on August 13, 1919, Dr. C. M. A. Stine and John Marshall visited Dayton. They were asked to submit other chemicals for testing and to figure the cost of aniline as an anti-knocking agent.

March 1, 1920, the research laboratories of the Dayton Metal Products Company were absorbed by General Motors and became an independent division, housed in a former Dayton-Wright airplane factory building at Moraine City, near Dayton. The anti-knock research, up to this point (July 1, 1917 to February 28, 1920) had cost \$42,000. The range was broadened and the sights lifted to embrace not only anti-knock and carbon-dissolving compounds, but also the possibility of extending the liquid fuel resources of the country. Accordingly, Boyd went to Yale to search the literature of cellulose chemistry<sup>27</sup> and later Midgley and Carroll A. Hochwalt studied selenium compounds, specifically ferrous selenide, as cracking catalysts.<sup>28</sup>

April 6, 1921, a fresh start was made by the discovery that selenium oxychloride had excellent anti-knock properties. The suggestion came from Kettering who read a lurid newspaper account of the discovery of the "universal solvent" by Professor Victor Lenher<sup>29</sup> of Wisconsin University. This was selenium oxychloride and the compound was skeptically tried out, for chlorine and oxygen had proved to be two elements which promoted knocking. In fact, sulfur oxychloride, tested at the same time, was almost the finest knock-inducing agent found. But selenium oxychloride acted differently. Plainly selenium was an element worthy of careful investigation, and Hochwalt prepared diethyl, methyl, propyl, and phenyl selenium and also made the corresponding tellurium compounds from a sample supplied by the American Smelting & Refining Company. All these were promising anti-knock agents. These encouraging discoveries led to an investigation of compounds based on the periodic arrangement of the elements. For this purpose a special arrangement of the periodic table by Robert E. Wilson, based on Langmuir's theory of atomic structure,<sup>30</sup> was used. This new approach prompted the study of metallo-organic compounds.

medal, but also the Nichols, Gibbs, Priestley, and Perkin. As popular as he was able, Midgley was Am. delegate to the Internat. Cong. Chem. at Rome, 1938, and dir. and pres. of the Am. Chem. Soc. At the time of his untimely death he was vice-pres. of Ethyl Gasoline Corp. and Kinetic Chemicals, Inc.

\* U. S. Pat. 1,490,223 (1924).

Between August and December 1921, it was demonstrated that anti-knocking is a periodic function of the elements and highest at the bottom of the columns. Having found tetraethyl tin excellent, Midgley and Hochwalt prepared a few cubic centimeters of tetraethyl lead, December 9, and with Midgley and Boyd, tested 1/40 of 1 per cent of this in kerosene. The result was better anti-knock properties than 1.3 per cent of aniline, which compound had been established as the standard. The hunt for a satisfactory anti-knock agent had ended.

But the engineering development of a commercially practicable anti-knock compound had only just begun. Among the several problems remaining to be solved, and on which three more years of careful research were expended, were two of particular importance. The first was to develop a practical method of making tetraethyl lead in quantity; the second was to overcome the difficulties of burning tetraethyl lead in an engine. Bromine was found necessary to the solution of one of these difficulties—that of preventing the formation of lead oxide during combustion and its deposition on valves and in the combustion space. Since it appeared that for this purpose bromine would be needed in amounts far larger than had ever been available before, an intensive search was made for further supplies of bromine. That hunt led to the further research which showed that bromine could be extracted from the sea, where it is present in inexhaustible amount, but in a minute concentration of only 65 parts per million. In research on methods of making tetraethyl lead the General Motors staff at Dayton evolved a method based on zinc ethyl to produce tetraethyl lead at a cost of approximately \$7.50 a gallon and a 100-gallon-a-day pilot plant was set up. Robert E. Wilson and Charles S. Venable, then both professors at the Massachusetts Institute of Technology, were called upon for consultation and research and later this work was successively in charge of Walter C. Whitman and George Calingaert.

At an American Chemical Society meeting, Midgley learned from Dr. Charles H. Milligan that he had found normal propyl compounds easier to prepare and more stable, which suggested a new way to make the sodium-lead process “go,” and a whole new series of laboratory experiments were undertaken which resulted in development of the sodium-lead process of making tetraethyl lead employing ethyl bromide.

In July of 1922 Willis F. Harrington, Elmer K. Bolton, and William S. Calcott of du Pont came to Dayton to confer on whether the process at its present stage could be transferred to the Deepwater plant on an industrial scale. Obviously the work was beginning to duplicate, so on August 29 all engineering and production research was transferred to du Pont and the Massachusetts Institute of Technology, while Dayton concentrated on application and anti-knock problems.

An anti-knock agent suddenly appeared in the filling stations of New Jersey, offered by the Raritan Aniline Works of New Brunswick. Midgley and Sandford Brown of Bakelite bought a quart at a filling station in Belleville and it proved to be straight aniline. For some reason this idea did not catch on with the motoring public and it was soon dropped by Raritan.

The first public announcement of tetraethyl lead was a paper<sup>31</sup> read at the September 1922 meeting of the American Chemical Society in Pittsburgh, accompanied by a demonstration in a test engine. It was soon ascertained by Midgley and his associates that tetraethyl lead, as such, mixed in gasoline operated in an automobile but a relatively short time before the lead oxidized in the combustion chamber, thereby interfering with its performance. After very painstaking and intelligently applied research, Midgley found that ethylene dibromide added to tetraethyl lead very substantially eliminated such deposits, on which discovery he obtained a patent.

The first public sale of "Ethyl" gasoline was from the station of the Refiners Oil Company, 6th and Main Streets, Dayton, February 2, 1923, where gasoline, treated with 7 grams of lead triethylbromide and 1½ grams of carbon tetrachloride was sold at 24 cents a gallon against ordinary gas at 20 cents and 40 per cent benzol gas at 27 cents. To distribute "Ethyl" gas the General Motors Chemical Company was organized<sup>32</sup> in April 1923, with Kettering, president, Midgley, vice-president, T. S. Merrill, secretary, and M. L. Prentis, treasurer. The first two, with Charles S. Mott, Alfred P. Sloan, and Earle W. Webb, were directors.

The Standard Oil Company (Indiana) was the first major oil company to distribute "Ethyl" gasoline.\* Afterward Midgley went out to interest a number of oil companies in the East, and E. M. Clark and Frank A. Howard,† president and vice-president respectively, of the Standard Oil Development Company, were very receptive to the idea. Howard said frankly that his company would like to treat all its gas with an anti-knock agent at a cost of not more than 1 cent a gallon, adding that they had applied for patents for making tetraethyl lead by

\* "I know that all the East Coast companies, including Jersey, turned down 'Ethyl' gasoline and that Standard of Indiana was the first large company to market it and really put it on the map. As a matter of fact, I can claim credit for that, largely due to the fact that I had been in close touch with Tom Midgley and his development while I was still at M.I.T., and started in to sell it to the Indiana Co. soon after I joined forces with them. By virtue of our pioneering we got an exclusive five-year contract for its sale in our Middle Western territory, and only after we had gone into it in a big way did any other large company take it up." (R. E. Wilson, to author, Mar. 7, 1947.)

† Howard, born 1890 in Illinois, has been with Standard Oil since 1919, when he gave up law practice, to manage the Development Div. He became vice-pres. in 1927, pres. in 1933-44. He is a graduate of Geo. Washington U. (B.S., 1911; LL.B., 1914).

the ethyl chloride modification of the sodium-lead process which had been perfected by their consultants, Dr. Charles A. Kraus\* and Dr. C. C. Callis.

In order to take full economic advantage of the two discoveries—tetraethyl lead as an anti-knock agent and the cheaper ethyl chloride modification of manufacture—formation of a jointly owned company to manufacture and market the anti-knock compound was agreed upon by General Motors Corporation and Standard of New Jersey. The company formed was the Ethyl Gasoline Corporation<sup>33</sup> (changed to Ethyl Corporation, April 9, 1942). All rights to General Motors and Standard patents in the field of anti-knocks, and all assets of the General Motors Chemical Company, passed to the new company. Incorporation was in Delaware with 50,000 shares of \$100 value, both sponsoring companies purchasing 3,750 shares and two months later 2,000 additional, providing a working capital of \$1,150,000. Kettering was Ethyl's first president. He resigned shortly to devote full time to research activities, and was succeeded on April 21, 1925, by Earle W. Webb, who has been president ever since. In addition to Kettering, the first Ethyl officers were: Frank Howard, first vice-president; Midgley, second vice-president and general manager; Arch M. Maxwell, third vice-president and sales manager; Art Mitnacht, secretary and treasurer, and Chester O. Swain, general counsel. On the first board of directors were Sloan, Howard, Kettering, Maxwell, Midgley, Donaldson Brown, E. M. Clark, John T. Smith, W. C. Teagle, and J. A. Moffett, Jr.<sup>34</sup>

All necessary preliminaries had now been completed. Production had been smoothed out. Road tests had proved the product good. Organization had been completed. But sales ran suddenly into a stone wall.

Forty-five cases of lead poisoning, with four fatalities, broke out in the pilot plant of Standard Oil at Bayway where the ethyl chloride process was being tried out. Under flaming scareheads the news was carried across the country,<sup>35</sup> and a first-class case of hysteria was whipped up by some of the more sensational newspapers. Though the distribution of "Ethyl" gas was still extremely limited, the *New York World*, which went all out in a violent crusade, declared that "20,000,000 motor cars on American highways are belching exhaust gases impregnated with poisonous dope," and making no distinction between the manufacturing hazard which had occurred in an experimental plant and the possibility of a public health hazard which might exist through

\* Kraus was then prof. chem. at Clark, but in 1924 went to Brown. He was born in Knightsville, Ind., 1875, was B.S. from Kansas, 1898; fellow at Hopkins, 1899-1900; and Ph.D., Mass. Inst. Tech., 1908, where he taught till 1914. He was chmn., Chem. Div., Nat. Res. Council, 1932-33, and of the Chem. Sect., Nat. Acad., 1935-38; Am. Chem. Soc., pres., 1939; and recipient of the Nichols, Gibbs, Richards, and Franklin Inst. medals, and hon. D.Sc. from Kalamazoo and Colgate.

the use of gasoline containing tetraethyl lead, branded leaded gas as a health menace threatening the entire nation.<sup>36</sup>

The possibility of a lead hazard had been suspected and the problem was submitted to the Bureau of Mines which tested leaded gasoline in a special chamber built to determine the ventilation of the Holland Tunnel. This work was in charge of Dr. A. C. Fieldner, head of the Pittsburgh Station, assisted by W. P. Yant, with Dr. R. R. Sayers, chief surgeon of the Bureau and later its director, assisted by Dr. W. J. McConnell, checking the physiological data. In the midst of these tests the Bayway accident occurred. Although the Bureau of Mines published its findings, supported by a statement from the Chemical Warfare Service that there was no health hazard in the exhaust of "Ethyl" gasoline,<sup>37</sup> a number of states and municipalities hastily passed regulations forbidding its sale. The Surgeon General called a conference of health officials, industrial health and hygiene authorities, representatives of labor and of the companies involved,\* at his office in Washington, May 20, 1925.<sup>38</sup> Surgeon General Hugh S. Cumming appointed an investigating committee † of eminent physicians and scientists. Tests were conducted by Dr. James P. Leake, of the U. S. Public Health Service, and 252 persons who had been exposed to "Ethyl" gasoline fumes, including garage men and drivers of the test trucks, were medically examined. The conclusions of the committee were unanimous:<sup>39</sup> "There are at present no good grounds for prohibiting the use of 'Ethyl' gasoline of the composition specified as motor fuel, provided that its distribution and use are controlled by proper regulations."

Since the Surgeon General was without legislative authority, he proposed that all leaded gasoline be dyed as warning to the public not to use it for cleaning purposes, and more important, that all blending be done at main distribution centers and in not less than tankcar lots.<sup>40</sup> The Ethyl Gasoline Corporation agreed to abide by these proposals and ever since has provided in its contracts with oil companies that they shall also abide by these regulations. Production of Ethyl Fluid was resumed at the du Pont Deepwater plant where industrial health precautions were perfected which were approved by the New Jersey Department of Labor,<sup>41</sup> and May 1, 1926, just a year after suspending sales, they were resumed.<sup>42</sup> The price was reduced October 1, 1928, from

\* Kettering, Midgley, Webb, Maxwell, Edgar, and Kehoe for Ethyl Gasoline; Howard, Clark, C. O. Johns, R. A. Van Eaton, and Gilman Thompson for Standard Oil; Irénée du Pont, Harrington, Reese, and Chas. K. Weston for du Pont.

† These were Dr. David L. Edsall, dean of Harvard Med. Sch.; Dr. Wm. H. Howell, prof. physiol., Hopkins; Dr. A. J. Chesley, exec. health officer, State Minn.; Dr. Reid Hunt, prof. pharmacol., Harvard Med. Sch.; Dr. Waller S. Leathers, prof. preventive med., Vanderbilt; Dr. Julius Stieglitz, prof. chem., Chicago; and Dr. C.-E. A. Winslow, prof. pub. health, Yale.

1 cent per cubic centimeter to 0.7 cent, and further reduced on August 15, 1929, to 0.5 cent.\*

During the long hunt for tetraethyl lead, rumors periodically reached Dayton that the I.G. had perfected a superior anti-knock agent. When Kettering was in Paris, November 1924, on the search for bromine supplies,† he received a letter from Jasper Crane, then du Pont's European representative, telling him that a Badische director had confirmed these stories, and later Kettering and Crane called on Dr. Bosch at Ludwigshaven. The head of the I.G. and his associates, Dr. Müller-Cunradi and Wilhelm Gaus, were very secretive, but they did demonstrate a performance test for their visitors. Kettering suspected the reagent was iron carbonyl. As early as August 1922, nickel and cobalt carbonyl had both been tested at Dayton and found to be good anti-knock agents. Attempts to make iron carbonyl had failed because of the high pressure necessary. Bosch suggested pointedly that they give up the hunt and buy I.G. material at 25 cents a pound. With great difficulty, months later, a small sample was obtained for testing which confirmed the iron carbonyl guess and showed that the material developed spark-plug troubles which could not be eliminated. Later the I.G. gave up iron carbonyl which it had started to market in Europe as Motalin, and obtained the German rights to tetraethyl lead.<sup>43</sup>

While this anti-knock additive, catalytic cracking, and hydrogenation were all injecting chemistry into gasoline refining, parallel chemical developments in lubricants were advancing step by step, although the first refining agents, sulfuric acid and caustic soda, had a bad reputation because they could not be properly cleaned up and the quality of the lubricant suffered. Again the automobile animated this progress. Early efforts to improve lubricating oil centered on the removal of wax. While light solvents were used in laboratory practice, purely physical methods, first freezing, and later high-speed centrifuging introduced about 1920 by Max B. Miller and P. T. Sharples,<sup>44</sup> were the mainstay of dewaxing upon which naturally evolved a long series of improvements and economies. The first commercial plant specifically designed for solvent dewaxing was at the Indian Refining Company at Lawrenceville, Illinois <sup>45</sup>—later owned by the Texas Company—using acetone-benzene as a solvent according to the specification of F. X. Govers' patent. ‡ Towards the close of the decade, the Texas Company at Port Arthur and the Tide Water Oil Company at Bayonne installed the Weir

\* Subsequent price reductions have been: July 1936, 0.28¢ per cc.; July 1939, 0.25¢; May 15, 1940, 0.23¢; Apr. 1941, 0.20¢; Apr. 1942, 0.18¢.

† See Chap. 16.

‡ U. S. Pat. 1,945,350 (1934).

process,\* which like the other physical processes utilized naphtha as a diluent, the wax particles being actually removed by filtering.<sup>46</sup> The more efficient, large-scale solvent dewaxing, particularly with propane, butane, and methyl ethyl ketone, came rushing forward only after 1930.

In 1924 Standard Oil of California built an Edeleanu sulfur dioxide plant at Richmond, California, to refine kerosene and specialty grades such as cosmetic oils, and by 1926 the Tide Water Associated Oil Company treated transformer oils at its Avon, California, refinery with sulfur dioxide.<sup>47</sup> The purpose was to produce lubricants from California crudes to compete locally with the highly favored Eastern—especially Pennsylvania—lubricants. Later the same company adopted this method † for the improvement of special products, such as turbine oils, at its Bayonne refinery.

In 1929 a new measure of lubricant quality was devised which stimulated these chemical developments. Viscosity had been emphasized to the Standard Oil Development Company because improvements in the viscosity index had been effected through solvent treatment with phenol at the Sarnia refinery of its Canadian subsidiary, and by hydrogenation at the experimental plant at Bayway. A simple, comparative chart devised by E. W. Dean and G. H. B. Davis of Standard Oil was published and quickly adopted as a simple standard by many other refineries. More than this, it stimulated other investigators and drew attention to this lubricating property.<sup>48</sup>

In the natural gasoline branch of the industry, where chemistry had promptly won a foothold, progress during the 1920's was sensational. Behind the chemical exploitation of the hydrocarbons, especially the olefins, in natural and refinery gas by Barnsdall and Standard of New Jersey, by Sharples and Carbide and Carbon, ‡ there was a rapid evolution in the use of the gas itself and methods of its treatment. The old compression process, producing so-called casing-head gasoline, fell rapidly into disuse. As early as 1923 no new compression plants were built and many in operation were worked in combination with the oil-absorption process, while ten new plants were erected to employ the recently discovered charcoal process.<sup>49</sup> This last, though short-lived, eliminated the old wasteful practice of weathering by which the dissolved gases methane, ethane, and propane were allowed to escape, and made their fractionation and recovery simple and feasible.<sup>50</sup> With the use of the pressure-absorption process and pressure rectification of light refractions, the supply of these gases was greatly increased, leading to

\* J. W. Weir and W. J. Ryan, Jr., U. S. Pats. 1,509,325 (1924); Weir, U. S. Pat. 2,005,062 (1935), ass. to Texas Co.

† Sulfur dioxide proved satisfactory on wax-free stock, but for wax-bearing lubricants a two-component process, sulfur dioxide-benzene, was evolved during the early 1930's.

‡ See Chap. 12.



the development of the bottled gas business by Phillips Petroleum and Carbide and Carbon, and to the enrichment of water gas at municipal gas plants.<sup>51</sup>

Summarizing the progress made in the chemical employment of these hydrocarbon gases, W. B. Campbell of Philfuels Company told<sup>52</sup> the Compressed Gas Manufacturers' Association at their meeting in New York, January 1930, that there was but a single manufacturer marketing liquid propane for industrial purposes in 1928, but he had increased his shipments sevenfold in 1929, when seven other large gasoline manufacturers had entered the field; that at the beginning of 1929 there was but one plant producing butane-air carbureted gas, while at the close of the year 16 were in operation or construction; that propane, butane, mixtures of the two, two grades of commercial pentane, and three grades of special solvent hydrocarbons, were now commercially available. All this was more than a mere promise. A new branch of the chemical industry had sprouted, one which grew gradually in the next twenty years into the trunk of its most prolific developments and its most profitable tonnage operations.

#### REFERENCES

1. B. T. Brooks, to author, Feb. 20, 1947; D. H. Killeffer, *Ind. Eng. Chem.* 18, 1041 (1926).
2. *Chem. Met. Eng.* 34, 85 (1927).
3. E. Owen, *ibid.* 35, 610 (1928).
4. *Ibid.* 34, 238 (1927); Owen, *op. cit.*; G. Egloff, *Ind. Eng. Chem.* 27, 648 (1935); B. T. Brooks, *Chem. Ind.* 44, 146 (1939); E. C. Williams, *ibid.* 495.
5. *Chem. Met. Eng.* 34, 238 (1927).
6. C. O. Willson, *Oil Gas J.* 95 (Mar. 1, 1928).
7. U. S. Pat. 1,392, 629 (1921); Brooks, in *Science of Petroleum*, III, p. 2081.
8. Brooks, in *Science of Petroleum*, III, p. 2084; *Chem. Met. Eng.* 34, 238 (1927).
9. Owen, *op. cit.*
10. *Ibid.*; L. de Florez, *Nat. Petroleum News* No. 17, p. 75, No. 49, p. 33 (1929); Brooks, in *Science of Petroleum*, III, p. 2085; *Ind. Eng. Chem., News Ed.* 9, 64 (1931).
11. *Chem. Met. Eng.* 34, 238 (1927).
12. E. B. Miller, *Trans. Am. Inst. Chem. Engrs.* 15, 241 (1923).
13. Brooks, *Chem. Ind.* 44, 146 (1939).
14. L. Edeleanu, *Am. Inst. Min. Engrs., Bull. No. 93*, 2313 (1914).
15. F. A. Howard, to author, Feb. 10, 1947; W. Miller and H. G. Osborn in *Science of Petroleum*, II, p. 1468.
16. *O.P.D. Reptr.* 46 (Jan. 8, 1923).
17. *Drug Chem. Mkts.* 17, 429 (1925); *Chem. Met. Eng.* 34, 123, 124, 467, 514 (1927), *O.P.D. Reptr.* 21 (Aug. 15, 1927).
18. *Wall St. J.* cable from London, quoted in *Chem. Mkts.* 21, 272 (1927).
19. Co. memo to author; S. D. Kirkpatrick, *Chem. Met. Eng.* 36, 332 (1929); *Chem. Mkts.* 25, 179, 625 (1929).
20. Primary source on these experiments, R. T. Haslam and R. P. Russell, *Ind. Eng. Chem.* 22, 1030 (1930).
21. Kirkpatrick, *Chem. Met. Eng.* 46, 672 (1939).
22. *J. Soc. Automotive Engrs.* 5, 128 (1919).
23. *Ibid.* 129.
24. C. F. Kettering, *ibid.* 4, 263 (1919); T. Midgley, Jr., *ibid.* 7, 489 (1920).
25. H. S. Tegner, *Petroleum Times* 19, 750 (1928).
26. Midgley, *Trans. Soc. Automotive Engrs.* 15, 317 (1920); *J. Franklin Inst.* 201, 123 (1926).

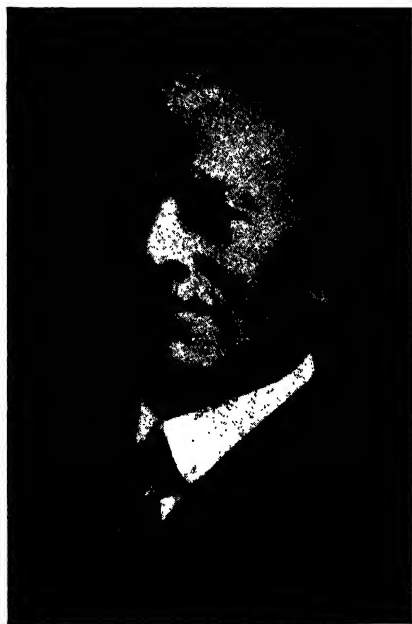


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*Oil, Paint & Drug Reporter.*

HOWARD E. FRITZ

27. T. A. Boyd, *Ind. Eng. Chem.* 13, 836 (1921).
28. Midgley and C. A. Hochwalt, *ibid.* 16, 365 (1924).
29. V. Lenher, *J. Am. Chem. Soc.* 43, 29 (1921).
30. I. Langmuir, *ibid.* 41, 868 (1919).
31. Midgley and Boyd, *Ind. Eng. Chem.* 14, 894 (1922); see also Midgley, *ibid.* 15, 421 (1923).
32. *Chem. Met. Eng.* 28, 742 (1923); *O.P.D. Repr.* 48B (May 7, 1923), 68 (June 11, 1923).
33. *Chem. Met. Eng.* 29, 815 (1923); Kirkpatrick, *ibid.* 46, 672 (1939); *Ind. Eng. Chem.* 15, 1197 (1923); Tegner, *op. cit.*
34. E. W. Webb, to author, Mar. 12, 1947; *Chem. Met. Eng.* 31, 321 (1924); *O.P.D. Repr.* 68 (Aug. 25, 1924).
35. *N. Y. Times* Oct. 28 & 31, Nov. 1, 1924, May 5, 1925; *Buffalo Express* Nov. 27, 1924; *N. Y. Post*, May 6, 1925; *Chem. Met. Eng.* 31, 712, 713 (1924); *Ind. Eng. Chem., News Ed.* 2 (Nov. 10, 1924); *O.P.D. Repr.* 19 (Nov. 3, 1924).
36. *N. Y. World* May 5 & 6, 1925.
37. R. R. Sayers, A. C. Fieldner, and others, Bur. Mines., *Repts. of Investigations* No. 2661 (1924); *Chem. Met. Eng.* 31, 793 (1924).
38. *Pub. Health Bull. No. 158* (1925); *Drug Chem. Mkts.* 16, 1328, 1557, 1716 (1925); *Chem. Met. Eng.* 32, 590 (1925); *O.P.D. Repr.* 34 (June 15, 1925); *Ind. Eng. Chem.* 17, 552 (1925).
39. *Pub. Health Bull. No. 163* (1926); *Drug. Chem. Mkts.* 18, 169 (1926); *O.P.D. Repr.* 21 (Jan. 25, 1926).
40. *O.P.D. Repr.* 20 (Mar. 15, 1926).
41. *Ibid.* 34 (May 18, 1925).
42. Webb, *op. cit.*
43. *Chem. Mkts.* 19, 275, 1111 (1926); *Chem. Trade J.* 79, 674 (1926).
44. McD. Gray, *Petroleum Engr.* 130 (Nov. 1930); Miller and Osborn, *op. cit.* p. 1471.
45. Miller and Osborn, *op. cit.* p. 1473.
46. *Ibid.*; N. E. Loomis, to author, Mar. 4, 1947; R. E. Wilson, to author, Mar. 7, 1947.
47. Miller and Osborn, *op. cit.* p. 1473.
48. *Ibid.* p. 1474; orig., *Chem. Met. Eng.* 36, 618 (1929).
49. *Min. Res.* 1923, II, 360.
50. Killeffer, *Ind. Eng. Chem.* 16, 995 (1924).
51. R. T. Elworthy, *Ind. Chemist* 4, 275 (1928) & *Chem. Mkts.* 23, 265 (1928); *Chem. Met. Eng.* 35, 772 (1928).
52. *Chem. Met. Eng.* 37, 103 (1930).

## *Chapter 25*

### CHEMICALS IN INDUSTRY

MECHANICAL INDUSTRIES ADOPT CHEMICAL METHODS AND MATERIALS—IMPROVED ACCELERATORS, NEW ANTITOXICANTS, USE OF LATEX ADVANCE RUBBER COMPOUNDING—CARBON BLACK PRODUCERS MOVING WESTWARD—MIXED FIBERS CREATE NEW FABRICS—SOUTHERN AND NORTHWESTERN EXPANSION OF PAPER PRODUCTION—GLASS AND CERAMICS, TANNING, REFRIGERATION, AND FOODSTUFFS COME UNDER NEW CHEMICAL INFLUENCES.

**C**HEMICALS CONTINUED TO PERCOLATE through the fabric of American industry. They moved in increased volumes along customary channels to the industries where they were employed in modifying raw materials and finishing products. But during the twenties they infiltrated the thinking in these industries which began consciously to seek chemical methods that might cut costs, improve products, and create new sales appeals.

This divergent conception of the role of chemicals in fabricating fields changed the attitude of the industry's best customers from passive acceptance to open-minded reception. To mutual advantage, buyer and seller began talking the same language. Better understanding was promoted by the growing practice among chemical makers of rendering technical services and by the employment of more technically trained men in the mills and factories of the mechanical industries.

Among the fabricating industries awakened interest in chemical products and processes had economic roots. Following the Industrial Revolution, the swift development of machinery riveted attention upon mechanical improvements. The manufacturer who went bankrupt was he who permitted his plant to become obsolete. After World War I, however, the emphasis changed from cost to quality, so that now the manufacturer who failed was the one who allowed his product to become obsolete. This radical change in American buying habits was incited, in part at least, by the new synthetic materials. The ready acceptance of plastics was a portent; rayon, an omen, for synthetic fabrics put "silk stockings," traditional symbol of luxury, on the legs of every parlormaid and salesgirl. Responding to these coercive influences of the Booming Twenties, manufacturers of all kinds of consumer

wares found chemical methods and chemical materials\* the readiest means of giving their goods fresh, desirable qualities: better adaptability to specific uses, greater durability under exacting conditions, novelty in form and texture, bright and striking colors, subtle appeals to the senses of touch and smell.

Plainly, all this was of inestimable advantage to the chemical industry. Its markets were broadened. Its opportunities became almost limitless. Within the industry itself, among its industrial customers, throughout the American people, these postwar changes did much to thaw that frigid inertia that believed "what was good enough for grandfather is good enough for me." Most of the material progress that survived this amazing decade arose from the so-called chemicalization of the mechanical industries. These developments have therefore a very special bearing upon the history of the chemical industry during these years and in the trying decade that followed.

The rubber industry had become almost a chemical industry. Starting with a raw material distinguished among all the products of nature by two unique properties, elasticity and resilience, it had so modified the milky sap of the hevea tree, generally known as latex, that it was successfully adapted for such different uses as the barrel of a fountain pen, an elastic band, a bath sponge, and above all an automobile tire whose tread withstands shock and abrasion and whose sidewalls stand up under constant flexing. Compounding was the secret of this amazing versatility and the art of rubber compounding had already grown up into an applied chemical science.

Rubber's extreme price fluctuations abetted chemical research. In the postwar slump, New York quotations in 1922 slid down to 11½ cents a pound. Three years later, thanks to the stringent export control from British plantations known as the Stevenson plan,† the price was \$1. As ten years before, when failing natural supplies enabled the Brazilians to shove the price up to the all-time record of \$3.05, exorbitantly costly rubber encouraged the chemist not only to improve rubber-compounding processes, but also to hunt for synthetics and to rework stocks of used rubber. There was no particular technical advance in reclaiming rubber over the alkali process discovered back in the 1890's by Arthur H. Marks. However, compounders had learned how to use reclaimed stock, so the quantity used mounted rapidly until in 1928 it accounted

\* For estimated consumption of heavy chemicals in these manufactures, 1927, see Appendix XLVIII.

† Engineered by forceful Sir James Stevenson, the quota system operated with varying success for 6 yrs. It was broken because the Dutch and hundreds of small native planters never joined, and the British planters found themselves in the uncomfortable position of restricting themselves out of an expanding market. (See Haynes and Hauser, *Rationed Rubber*, p. 58; Wolf, *Rubber*, p. 222; Wilson, *Trees and Test Tubes*, p. 104.)

for 51 per cent of the total consumption.<sup>1</sup> Synthetic rubber remained pretty much in the discussion stage,<sup>2</sup> but the first acceptable rubber substitute, Thiokol, appeared in 1923 and in 1925 du Pont began the research which eventuated in Neoprene.<sup>3</sup>

Thiokol was a chance discovery. In Kansas City, Dr. J. C. Patrick, back after several years' service as chemist for Armour & Company in South America, was endeavoring to find a more satisfactory anti-freeze. He mixed ethylene dichloride with sodium polysulfide, and on adding a little acid, got a stiff, gummy coagulum.<sup>4</sup> Despite its lack of elasticity, Patrick recognized its valuable rubberlike properties and began manufacturing in an experimental way. Bevis Longstreth,\* president of the Western Salt Company, became interested and financed the organization of the Thiokol Corporation, moving the operation to Trenton, New Jersey, then second largest rubber center in the country. The material proved highly resistant to gasoline and its first commercial application was as lining for gas-delivery hose.

In the sphere of compounding, organic accelerators continued to multiply, but most of the newcomers were but derivatives of chemicals whose merit in vulcanization had already been proven. For example, the *Dye Census* for 1926 reported as new, crotilidine aniline, *p*-ditolylthiourea from du Pont, thiocarbo-*p*-toluidide from National Aniline, and dimethylamine from du Pont and Wolff-Alport.<sup>5</sup> In 1925 thio-carbanilide continued to be the most popular accelerator, with production reaching 2,352,000 pounds, while hexamethylenetetramine stood second at 1,658,000 and diphenylguanidine, third, at 1,204,700 pounds.<sup>6</sup> Only these three, among the scores of accelerators on the market, passed the million-pound mark, although in the next few years the sales of diphenylguanidine and its derivatives were to increase very rapidly at the expense of hexamethylenetetramine.

The well-snarled guanidine patent situation was straightened out during these years. The Dovan Chemical Corporation had been organized in 1920 by Henry S. Doty and Van Lear Woodward† to exploit the diphenylguanidine patent (U. S. 1,411,231) granted to Morris L. Weiss,‡ March 28, 1922. The patent had hardly been issued before

\* Longstreth sold his interest in Western Salt, 1930, and moved to Trenton to assume active management of Thiokol. In the meantime manufacturing was transferred to Dow Chemical which, producing ethylene dichloride, was in a strategic position to take over production, leaving Longstreth to concentrate on sales.

† Doty and Woodward had both been with the importing house of Frazar & Co. Doty was trained at Columbia (B.S., 1905) and between 1905-17 had been chief chem. in charge of compounding, reclaiming, and "specification goods" at the Manhattan Rubber Mfg. Co., Passaic, N. J. Woodward, after attending Hackley Sch., became a salesman for McKesson & Robbins, then mgr., Chem. Dept., at Frazar, and finally vice-pres. and mgr. of States Metal Co.

‡ Born in Russia, 1887, Weiss studied chem. at Cooper Union and Bklyn. Polytech.

Dovan sued National Aniline for its infringement.<sup>7</sup> National Aniline maintained that the disclosure of the Weiss patent had long been anticipated when, at the meeting of the American Chemical Society in September 1919, Dr. George D. Kratz of the Falls Rubber Company read a paper describing the action of diphenylguanidine as an accelerator, and that in fact he had used this material in rubber vulcanization, made inner tubes, and sold them as early as 1917.<sup>8</sup> This litigation, which later involved the suit of Dovan against the Corona Cord Tire Company,<sup>9</sup> resulted in four reversals and two contradictory decisions.\* The case eventually reached the Supreme Court which, on April 9, 1928, declared the Weiss patent invalid.<sup>10</sup>

Further to complicate the situation, in 1925 the Examiner of Interferences at the Patent Office awarded 13 of the 16 claims of a patent by Winfield Scott assigned to du Pont for di-*o*-tolylguanidine, which Dovan promptly appealed and eventually lost.<sup>11</sup> Now came the climactic confusion, for the Grasselli Chemical Company, superseding all claims, sued National Aniline for violation of U. S. Patent 1,149,580, issued to F. Hofmann and K. Gottlob, which patent it had acquired in the purchase of the Bayer Company's assets from the Alien Property Custodian during World War I.<sup>12</sup> The German claims were typically broad, covering as accelerators all organic ammonium compounds having a basic reaction at vulcanization temperatures and a disassociation constant greater than  $10^{-8}$ , a definition that included practically every accelerator then in common use. If this blanket patent were sustained, damages and royalties collectable were figured in the millions of dollars, and representatives of all the rubber companies were present when Judge A. N. Hand in the U. S. District Court for the Southern District of New York, declared the patent invalid for lack of adequate invention.<sup>13</sup> When this decision was clinched by the Supreme Court ruling on the Weiss patents, the door to the guanidine accelerators was thrown wide open and the immediate effect was a precipitous price decline. Diphenylguanidine dropped from 64 to 40 cents, and di-*o*-tolylguanidine from 71 to 49 cents.<sup>14</sup> In 1929 the Dovan Chemical Corporation closed up its affairs,† turning over its existing obligations and rights to Roessler & Hasslacher.<sup>15</sup>

and was chem. with the Republic Rubber Co., Youngstown, O., 1917-20. He had charge of the Dovan experimental plant and labs. in Newark, N. J.

\* Dovan won from National Aniline in the N. Y. Dist. Court; decision reversed in the Circuit Court. Dovan lost to Corona in the Pittsburgh Dist. Court; decision reversed in the 3rd Circuit Court of Appeals; and this in turn reversed by the U. S. Supreme Court.

† "At the time of the Supreme Court decision (1928) several companies were making diphenylguanidine and as Dovan could not make sufficient profit at the lower prices on their share of the business, we gradually drifted out of the accelerator business. I don't remember that we turned over our rights or obligations to anyone in particular



The signal contribution of the twenties to rubber compounding, however, was the successful application of antioxidants which retard the deterioration of vulcanized rubber from aging. It had been observed that some organic accelerators, especially *p*-aminodimethylaniline, one of Oenslager's early discoveries, had a beneficial antioxidizing action, and early in the 1920's this problem was deliberately studied. The first antioxidant<sup>16</sup> was a condensation product of aldol ( $\alpha$ -hydroxybutyraldehyde) and  $\beta$ -naphthylamine.\* In 1926 du Pont put on the market Antox, a condensation product of butyraldehyde and aniline, followed the next year by Neozone, phenyl-1-naphthylamine.<sup>17</sup> Thereafter progress was rapid. A great number of compounds, commonly patented and trade-named, were offered to control the degeneration of vulcanized rubber by oxidation.

Commercial shipments of latex from the Far East began in commercial quantities during the early 1920's, promoted by successful preservation by means of ammonia or formaldehyde and much stimulated by the development of practical methods of concentrating the liquid by centrifuging,<sup>†</sup> by creaming,<sup>‡</sup> and most especially by the so-called Revertex process of evaporation developed by Ernst A. Hauser (U. S. Pat. 1,729,-651, 1929). By offering the rubber industry a more flexible material, in liquid or in paste form, latex not only revised vulcanizing§ and compounding techniques, but also opened up new opportunities, not only in such novelty forms as crepe and sponge rubbers, but in rubber-impregnated fabrics, including cord tires, in rubber-coated paper, in rubber paints, and in rubber adhesives.<sup>18</sup> The United States Rubber Company showed particular interest in this material, and Ernest Hopkinson¶ carried on investigations of its compounding in the New York laboratories and later in a pilot plant at New Durham, New Jersey, during which the sprayed rubber process was developed.<sup>19</sup> At Akron the B. F. Goodrich Rubber Company also embraced this new opportunity. At this time also an intensive study was made of artificial rubber dispersions by Harlan L. Trumbull and John B. Dickson, who later became director of research of A. G. Spaulding & Bros.<sup>20</sup>

In 1906 in France, Victor Henry had learned that latex particles in suspension carry a negative electric charge, and in 1925 from the Kodak

as unfortunately we didn't have much left. We did make some sort of a deal with Dow Chemical Co. on a process for making diphenylguanidine from sodium cyanide which we had developed and had been using." (H. S. Doty, to author, Feb. 26, 1947.)

\* H. A. Winkelman and H. Gray, U. S. Pat. 1,515,642 (1924), ass. to Goodrich.

† W. B. Wescott, U. S. Pats. 1,630,411-12 (1927).

‡ J. McGavack, U. S. Pat. 1,647,805 (1927), ass. to Naugatuck Chemical Co.

§ P. Schidrowitz, U. S. Pat. 1,443,149 (1923).

¶ Born and educated in England, Hopkinson (1872-1933) began his career with United States Rubber in 1897 as patent counsel, becoming vice-pres. in 1919. To him goes most of the credit for developing the three outstanding methods of tire manufacture.

laboratories, S. E. Sheppard and L. W. Eberlin reported<sup>21</sup> that rubber could be deposited on an anode. The following year Goodrich\* and Kodak, and abroad Dunlop Rubber and the Hungarian Rubber Goods Company, organized American Anode, Inc.<sup>22</sup> This process of electroplating was now applied both in coating metals with rubber and in the manufacture of so-called "dipped" goods such as bathing caps and surgeons' gloves.<sup>23</sup> Also at Goodrich, and stemming from these same researches, came an early rubber substitute. Howard E. Fritz† who was in charge of selling rubber-lined tanks made by the recently perfected Vulcalox process, urged the management to continue the researches of Harry L. Fisher and Dr. Waldo L. Semon.‡ Fisher had found a methyl-rubber isomer which bonded rubber to metal, in searching for a synthetic-rubber tank lining,<sup>24</sup> while Semon, in attempting to dehalogenate the insoluble polyvinyl chloride, had discovered an elastic plastic out of which was developed Koroseal.<sup>25</sup>

Among many novel applications of latex was its use in the manufacture of can sealers. This was worked out in 1926 by the Dewey & Almy Chemical Company, Cambridge, Massachusetts, organized<sup>26</sup> in 1919 by two young chemists associated together in the Chemical Warfare Service, Bradley Dewey and Charles Almy.§

A direct repercussion of these chemical activities was the expansion of United States Rubber Company's subsidiary, the Naugatuck Chemical Company. Launched during the war to provide its parent with critical aniline, it began postwar to manufacture rubber chemicals for sale; to distribute latex from United States Rubber's plantations; and to manufacture latex compounds for consuming industries.<sup>27</sup> In 1929 the

\* At Goodrich this electroplating work with latex was done by H. Howard, E. B. Newton, and C. L. Beal.

† Fritz, born in 1888 and educated at Ohio State (Ch.E., 1923; Ph.D., 1924), had been with Hooker Electrochemical Co., 1916-20, and on the chem. faculty of his Alma Mater, 1921-25.

‡ First prominently identified with the early development of antioxidants, and later with synthetic rubber, Semon came to Goodrich in 1926 from Washington U. (Seattle) where he won his Ph.D. in 1923. Since 1940 he has been dir., synthetic rubber research and vice-pres. of Hycar Chemical Co. till 1942. He received a Modern Pioneer award of the Nat. Assoc. Mfrs., 1940.

§ Born in Vt., 1887, educated at Harvard (A.B., 1908), and Mass. Inst. Tech. (B.S., 1909), Dewey was dir. research at American Sheet & Tin Plate before cofounding Dewey & Almy Chemical Co. in 1919, of which he is pres. He served in Gas Defense Div. in World War I and was first deputy and later chief of U. S. Rubber Admin., 1942-44, in World War II. He has hon. degrees from U. Akron, Northeastern, and Harvard, was given the D.S. and Chem. Ind. medals, and became pres., Am. Chem. Soc., in 1945. Almy, born in Mass., 1888, cofounder and vice-pres. of Dewey & Almy, attended Harvard (A.B., 1908) and Mass. Inst. Tech. (B.S., 1910). He taught at the latter and joined Chem. Warfare Serv. in 1918. For a time he was tech. dir., American Vulcanized Fibre Co., and gen. mgr., Virginia Red Oil Products Corp. He has been pres., Browne & Nichols Sch., since 1932.

Rubber Regenerating Company, another subsidiary which prepared reclaimed rubber, was consolidated with Naugatuck, and the purchase of Dispersions Process, Inc., put Naugatuck also into the manufacture of water dispersions of reclaimed rubber.

In the chemical industry itself, organic accelerators opened new markets to the coal-tar chemical makers, which du Pont and National Aniline promptly embraced. In 1929 Monsanto entered the rubber chemicals field with the acquisition of the Rubber Service Laboratories Company and its subsidiary, the Elko Chemical Company, having gross assets of \$1,500,000.<sup>28</sup> Rubber Service had been organized in 1920 by a group of rubber technologists, R. C. Hartong, president; Carl N. Hand and C. W. Bedford, vice-presidents; Clayton Olin North, formerly with Republic Rubber and Goodyear, secretary and treasurer and in charge of development; and Winfield Scott, who came from du Pont to be director of research. They purchased part of the Government plant at Nitro, West Virginia, where they were manufacturing at the time of merger eleven aldehyde-amine accelerators, thirteen other rubber chemical specialties, and several xanthates for mineral flotation. Indicative of these chemical influences, a series of patents was issued during 1925 to Carleton Ellis and his associates,\* assigned to the Chadeloid Chemical Company, which marked the beginning of the chlorinated-rubber coating compounds.

Two new compounding materials began to be used extensively at this time. Stearic acid was popular as a softener, partially replacing palm oil because of its superior action as a stabilizer of crude rubber and activator of accelerators.<sup>29</sup> Compounders, especially those working with reclaimed rubber, began using pine tar, product of the destructive distillation of pine wood, a material that had had a very limited market since the passing of sailing ships. The new demand revived this old industry which promptly met severe competition from Russia and Finland, so that Pitch Pine Products, Inc., American Turpentine & Tar Company, Wood Chemical Products Company, and Georgia Pine Turpentine Company filed a joint brief, during the Senate Finance Committee hearings on the 1929 Tariff Act, asking an increase of duty from 1 cent to 3 cents.<sup>30</sup> Though zinc oxide grew in use, carbon black continued to be the premier compounding material and the mounting production of tires made rubber manufacturers its greatest consumers.†

Increasing output of carbon black hastened the westward and southward trek of the industry. ‡ By the middle 1920's the Monroe, Louisi-

\* U. S. Pats. 1,544,529-34.

† In 1925 distribution of carbon black by industries stood: rubber, 86,329,000 lb., 49.2%; export, 43,183,000 lb., 24.6%; ink, 22,389,000 lb., 12.7%; paint, 11,757,000 lb., 6.7%; miscellaneous, 11,973,000 lb., 6.8%; total, 175,631,000 lb. (See *Min. Ind.* 1926, 509).

‡ See Vol. III, p. 106.

ana, field was the chief producing center. But the increasing delivery of gas to Baton Rouge, reaching 60,000,000 cubic feet a day in 1926, floods in 1927, and the increasing strictness of the Louisiana conservation laws, attracted the carbon industry toward the Panhandle of Texas where the Amarillo field was developing an enormous volume of cheap gas for which there was no other market.<sup>31</sup> The oil companies having large supplies of by-product residue gas from their casing-head gasoline plants were willing to market it at a sacrifice price. The Columbian Carbon Company, which had built the first carbon plant in the Monroe field in 1917, built the first Texas plant in Stephens County in 1923, and also the first in the Texas Panhandle at Wescar. By 1929 it had seven plants operating in the state.<sup>32</sup> Columbian, the largest producer of carbon black in the world at that time, operated through three subsidiaries, the Southern Carbon Company, the Western Carbon Company, and Coltexo Corporation.

Several other big plants<sup>33</sup>—Godfrey L. Cabot at Eliasville and Caddo, Texas, in 1926; the Kosmos Carbon Company at Alexander and Norrick, in 1927; and the General Atlas Carbon Company (previously the General Atlas Chemical Company) at Pampa in 1928—swung the balance to the Panhandle. Although in 1923 the Carson Carbon Company, organized by Ault & Wiborg Company with A. C. Ransom, built a plant near Monroe, Louisiana,<sup>34</sup> and in 1926 Cabot doubled its plant in the historic West Virginia field at Seth,<sup>35</sup> plants were beginning to appear in the Far West. As early as 1923, Columbian's Western Carbon subsidiary had built a \$325,000 unit at Colgate, Oklahoma, with Roy C. Morrison as manager.<sup>36</sup> The next year the Crystal Carbon Company opened up near Cisco, Colorado, and J. M. Huber, Inc., at Lance Creek, Wyoming.<sup>37</sup>

The biggest merger in gas black annals came in 1925 when the United Carbon Company incorporated in Delaware for \$50,000,000, to absorb carbon black and gasoline products properties of 15 companies,\* chiefly in the Monroe field.<sup>38</sup> Three of these companies, Kosmos Carbon, Natural Gas Products, and Cumberland Carbon, had all been organized, 1922-25, by Oscar Nelson,† general superintendent of the early Columbian Carbon operations in the Monroe field, who was elected

\* The consolidated companies were: Kosmos Carbon Co., Natural Gas Products Co., Cumberland Carbon Co., Louisiana Carbon Co., Liberty Carbon Co., Central Carbon Co., Standard Carbon Co., Humphreys Carbon Co., Pelican Gas & Carbon Co., Green River Carbon Co., United Oil & Natural Gas Products Corp., Consolidated Carbon Corp., Louisiana Gas Products Corp., Tampico Gas Co., and Fred Stovall, *et al.*

† Swedish-born, Nelson began as a laborer with the Raven Carbon Co. in W. Va., working up to supt. He resigned from Columbian in 1916 to form a partnership with T. A. Whelan and T. F. Koblebard, who both became officers of the new United Carbon.

president.<sup>39</sup> The next two years, several other carbon properties were acquired and in 1929 the company bought a minority interest amounting to \$2,365,000, in the Mississippi River Fuel Corporation, owners and operators of a gas pipe line from the Louisiana field to St. Louis.\* An important entry into the carbon black business in 1928 was Wishnick-Tumpeer, Inc., which bought the Century Carbon Company at Borger, Texas.<sup>40</sup> Wishnick-Tumpeer (now the Witco Chemical Company, an affiliate of Continental Carbon) had been started in 1920 as a chemical jobbing house in Chicago by Robert I. Wishnick and David Tumpeer.†

Carbon black makers, long reputed to be the most wasteful ‡ chemical operators, began researches to improve their processes. In 1924 Binney & Smith, distributors of blacks, installed the first testing laboratory, followed promptly by Godfrey L. Cabot, Inc., which organized a research department under C. R. Johnson.<sup>41</sup> An increase in the efficiency of the channel process and the installation of the furnace process in 1928 were the two big developments which came out of the laboratories, with production reaching 370,000,000 pounds in 1929.<sup>42</sup>

In the merchandising department, sales of Texas Carbon Industries, Inc., were taken over in 1924 by R. W. Greeff & Company, whose foreign trade connections were useful in the field.<sup>43</sup> Export always looms large in carbon black, since this country is the sole important world producer, and in 1929 the industry gathered itself together in the Carbon Black Export Association, incorporated in Delaware under the Webb-Pomerene Act.<sup>44</sup> At the time, this organization was said to represent more than 92 per cent of the world's output. §

\* "It so happens that the Mississippi River Fuel Corp. was organized in my law office, while I was at the bar, and Columbian Carbon had and has a larger financial interest therein than United. The only bearing of the enterprise on the carbon industry is this. When we found that large volumes of cheap residue gas would become available from the Texas gasoline plants, we set about to market our gas production in Louisiana, feeling that to the extent this was possible, we could replace the black production in Texas with a lower cost raw material. Our company pioneered in this effort, first building the pipe line to Monroe and installing a distributing plant in 1918, then building a 100-mile pipe line to Alexandria in 1921-22, then joining with Standard Oil in the Interstate line to Baton Rouge in 1923, then joining with other gas producers in the Mississippi line to St. Louis in 1928. United participated only in the last-mentioned line." (Reid L. Carr, to author, Mar. 3, 1947.)

† Bob Wishnick and Dave Tumpeer had both been with Max Woldenberg's A. Daiger & Co. Purchase of the carbon black plant was their first excursion into production which has been followed by other gas, oil, black, and asphalt properties. Wishnick, who studied chem. at Armour Inst., is pres. at N. Y., while Tumpeer, who is secy., has charge of Western sales out of Chicago.

‡ "This is a highly controversial subject. The channel process is wasteful of gas, but not as wasteful as flaring, which was done prior to its use by carbon black manufactures. Moreover, channel black imparts longer life to tires than other blacks produced in higher yields and thus in the long run may not be so wasteful." (W. F. Twombly, to author, Mar. 13, 1947.)

§ The original officers were N. L. Smith, Binney & Smith, pres.; Edmund Billings,

Possibly the longest chemical step forward in the textile industry during the 1920's was all that is implied in the change from "artificial silk" to "rayon." Favorable reception of the synthetic fiber led to its use on its own merits as a new material. More progressive mills began spinning combinations of various natural and synthetic fibers, innovations that created almost a new textile industry. Rumors of a practical synthetic wool roused interest and in 1925, when Snia Viscosa of Italy announced Sniafil, first product of this kind on the market,<sup>45</sup> the American Woolen Company and the Arlington Mills made experimental weavings and there were stories of the Italian firm erecting a plant in this country.<sup>46</sup> Apart from the beginning of fabric specialties created by mixtures of yarn, there was great progress in pyroxylin-coated fabrics. For example, at the suggestion of the Bookbinders' Guild in New York, the Fabrikoid Division of du Pont perfected a new book-binding cloth in 1927 and that year announced Muralart, a new wall fabric.<sup>47</sup> In this coated-fabrics field, the Atlas Powder Company acquired, in 1928, the Duratex Corporation of Newark.<sup>48</sup>

The first concentrated solution of hydrogen peroxide to be made in this country<sup>49</sup> appeared in 1925, reviving interest in this old and useful textile bleaching agent, and the following year its electrolytic manufacture was begun at Tonawanda, New York, by the Buffalo Electro-Chemical Company.<sup>50</sup> The enterpriser in this successful venture was Charles A. Buerck, president of the Hydrox Chemical Company, manufacturers of hydrogen peroxide by the old barium dioxide process. Associated with him were two Buffalo men, J. Frederick Schoellkopf, Jr., who became secretary, and Ansley W. Sawyer. Two years later, when the manufacture of persulfates was undertaken, the company started a 60 per cent expansion of plant capacity.<sup>51</sup> Attempts to modify and cheapen the old process of silk weighting by substituting tin-lead phosphate for tin tetrachloride, were but partially successful, for while the silk deteriorated more slowly, there were changes in color and the danger of lead poisoning through absorption by skin secretions.<sup>52</sup> The problem attracted attention and the Associated Dyeing & Printing Corporation announced its "W" system, an improved, combined weighting and finishing process evolved under the direction of its president, Dr. W. L. Wirbelaver.<sup>53</sup>

Increased use of mixed and impregnated fabrics raised questions as to proper labeling and quality-testing, which led the Bureau of Standards to call together a committee of the textile industry and the American Association of Textile Chemists & Colorists to set up fair standards

Godfrey L. Cabot, vice-pres.; R. H. de Greeff, R. W. Greeff & Co., secy.; G. A. Williams, United Carbon, treas.; H. W. Huber, J. M. Huber, Inc., asst. treas.; J. W. Herron, Palmer Gas Products Corp., and the above, dir.

for dyed fabrics.<sup>54</sup> In 1928 the National Retail Dry Goods Association began testing fabrics, after its survey had revealed vast quantities of inferior goods masquerading under accepted names. Shortly afterwards, Macy's department store set up a laboratory to do its own testing, and several months later the Viscose Company put into operation its "Crown tested" fabrics plan.<sup>55</sup> Within a few years most specialized fabrics were branded and sold under trade names.

Papermaking expanded towards the South and Northwest during the 1920's. This meant the handling of new wood species, involving a marked increase in the sulfate process in the South and a greater demand for sodium sulfate just when revision of the nitric acid process cut down the by-product supply of this chemical. The most conspicuous events of the decade were the huge kraft paper plants built on the Eastern seaboard from North Carolina to Florida, contributing to the sensational increase of kraft paper from 500,000 tons in 1926 to 1,000,000 in 1929.<sup>56</sup> But the invasion of the Northwest, though less publicized, was not less important. This region used the sulfite process on Western hemlock and Sitka spruce. Both migrations were prompted by diminishing wood supplies in the Northeastern and North Central regions and by improved paper technology, notably the multistage bleaching of sulfate pulp, which widened the use of woods. In the South they were aided by the growing market for kraft paper products, notably paperboard for cartons, and in the Northwest by the Panama Canal, which put that section on a freight-rate competitive basis with Eastern mills.<sup>57</sup>

Interest awakened in the chemistry of cellulose (encouraged also by the new uses of wood cellulose in the rayon and lacquer industries) and in chemical by-products of the pulping process, and in 1926 a research and development group was organized at the Marathon Paper Mills, Rothschild, Wisconsin, with Allen Abrams\* as director.<sup>58</sup> The following year the company increased its capital to \$5,000,000 and salvaging products from sulfite waste liquors began in a plant designed and operated by Guy Howard. From here came that waste-recovery project which so fascinates the layman's imagination, the synthesis of vanillin from sulfite liquor. Semichemical pulping was investigated thoroughly for five years at the Forest Products Laboratory and a process of isolating wood fibers with over 75 per cent yield was evolved.<sup>59</sup> The culmination of this technical interest was the formation in 1929 of the Institute of Paper Chemistry, a specialized, postgraduate

\* An outstanding technologist in the paper industry, Abrams, vice-pres., Marathon Corp., was trained at Washington & Jefferson (A.B., 1910; M.S., 1915, D.Sc., 1937) and Mass. Inst. Tech. (B.S., 1915). He was successively with Bemis Bros. Bag, Mead Pulp & Paper, and Cornell Wood Products, before joining Marathon in 1926 as dir. research. He worked with the Development Sect., Chem. Warfare Serv., 1917-19, was pres., Tech. Assoc. Pulp & Paper Ind., 1933-34, and during World War II in the Off. Strategic Serv.

school and research center located at Appleton, Wisconsin, supported chiefly by pulp and paper manufacturers paying dues based upon their annual production. Practical work proceeded in four directions: students working on their theses; staff work in pure science; problems presented by members; and research pursued for companies not eligible for membership.<sup>60</sup> All work was on a project basis, the charges being based on cost plus 15 per cent for overhead. The technical director was Otto Kress, and professor of organic chemistry, Harry F. Lewis.\*

Two waste-cellulose products came to fruition at this time. The not-new idea of pressed board was commercially achieved on a large scale for the first time in this country beginning 1922, by the Celotex Corporation, using bagasse, the spent cane stalks from sugar mills.<sup>61</sup> Also in the South, William H. Mason for many years associated with Thomas Edison, evolved his process of treating wood chips under 1,000 pounds-per-square-inch steam pressure in an autoclave, and "exploding" them into a fibrous mass which can be washed and formed into thick mats on a papermaking machine. Pressed hydraulically, these become the familiar Masonite boards.<sup>62</sup> Backed by businessmen of Wausau, Wisconsin, and Laurel, Mississippi, he organized the Mason Fibre Company which later became the Masonite Corporation.

Papermaking, always one of the chemical industry's best customers, was increasing its consumption markedly. Its use of liquid chlorine was the chief cause for the continually increasing chlorine production from the electrolytic alkali plants and its demand for salt cake made this once by-product a principal product of chemical manufacturing. To serve the many new Southern mills, the Georgia-Louisiana Chemical Company was organized in 1927 by Robert S. Perry, consulting chemical engineer and president of Perry & Webster in New York City, and built two alum plants in Atlanta and New Orleans. It was affiliated with the Western Paper Makers' Chemical Company of Kalamazoo, Michigan, itself a sort of cooperative selling and manufacturing association representing 21 different plants<sup>63</sup> producing alum, rosin size, casein, clays, mineral colors, alkalies, and other materials used in the pulp, paper, and coatings industries.† The following year this Southern venture was

\* Kress had been tech. expert in paper dyeing with Badische during World War I and was later associated with the Forest Products Lab., the Consolidated Water Power & Paper Co., and supt., Thilmany Pulp & Paper Co. He was born in New York and received his Ph.D. at Columbia, 1909. Outside of 2 yrs. with National Aniline, Lewis had taught chem. at Grinnell, Maine, Cornell Coll., and Ohio Wesleyan, where he was prof. chem., 1928-30. He studied at Wesleyan and U. Ill., Ph.D., 1916; wrote *Fundamentals of Organic Chemistry*; and has been chmn., Cellulose Div., Am. Chem. Soc., and of the Chem. Sect., Iowa Acad.

† These allied interests were represented among the officers. Perry was pres., Ralph M. Snell, vice-pres. and mgr., Charles H. Knight, an Englishman interested in several of the associated firms, was treas., while the secy. was C. K. Williams of the well-known



absorbed by the Paper Makers' Chemical Company and all of the associated companies consolidated\* in a single firm, the Paper Makers' Chemical Corporation,<sup>64</sup> capitalized at \$8,000,000.

In another big chemical-consuming field, glass and ceramics, the 1920's were signalized by an extraordinary number of technical advances. The use of automatic machinery, introduced in 1908 and opposed by the union with determination, won during this decade an established place in glass production and furthered centralization of production into three very large makers of window glass, two of plate glass, and four of bottles. The manufacture of tableware, because machinery was not largely applied, continued to be scattered in many small units.<sup>65</sup> A typical innovation was a continuous operation for production of plate glass at the River Rouge plant of the Ford Motor Company in 1923,<sup>66</sup> and these trends were underscored by the merger of Owens Bottle and Illinois Glass into the Owens-Illinois Glass Company in 1929.<sup>67</sup>

In chemical technology significant developments balanced these big events. Glass annealing was perfected and brought under chemical control, and "fluorspar glass," used for joining tubes of different melting points, appeared.<sup>68</sup> Commercial production of fused silica quartz glass in large quantities in an electric furnace, for which Dr. Edward R. Berry† was awarded the Grasselli medal,<sup>69</sup> came from the General Electric Company in 1924.<sup>70</sup> Laminated safety glass moved forward rapidly. Large-scale production dated from 1927, after Amory L. Haskell had organized and financially backed the Triplex Safety Glass Company of North America, and du Pont and Pittsburgh Plate Glass joined in an alliance, the Pittsburgh Safety Glass Company,‡ to manufacture Duplate.<sup>71</sup> Increased use of barium oxide<sup>72</sup> and the preparation of beryllium glass at the University of Pittsburgh by Chi Fang Lai and Alexander Silverman forecast the coming, specialized formulation of glass mixes under strict chemical control.<sup>73</sup>

In the sister industry of ceramics another southward movement was

pigment and dry color firm. With these officers, William J. Lawrence, pres. of Western Paper Makers' Chemical, and Eli Winkler, pres. of Isaac Winkler & Bro. Co., comprised the dir. (See *O.P.D. Repr.* 57, June 13, 1927.)

\* Paper Makers' Chemical Co., Western Paper Makers' Chemical Co., Vera Chemical Co., Vera Chemical Corp., Adirondack Mineral Co., Superior Sizing Co., John Regnier & Son Co., and Keystone Products Co.; and control of subsidiary Superior Pine Products Co., Vera Chemical Co. of Canada, Georgia-Louisiana Corp., and Empire Size & Chemical Co.

† Except for 1 yr. with Orono Pulp & Paper Co., the rest of Dr. Berry's career was with General Electric. He got his M.S. in 1907 from U. Maine, which also honored him with a D.Sc. He died in 1934 at the age of 55.

‡ Name changed to Duplate Corp. in 1929 and du Pont's 50% interest sold to Pittsburgh, Feb. 1931.

noticeable. The shortage of imported clays, refractory materials, talc, and other nonmetallic minerals during World War I awakened the South to a realization of these plentiful, valuable resources, and postwar their exploitation was seriously undertaken. To attract the needed capital, the state geological surveys explored promising deposits, ably supplemented by the industrial departments of the various railroads of the region. Typical of this endeavor was a young geologist from Johns Hopkins, Poole Maynard,\* who first as assistant state geologist of Georgia, and later as consultant to the Central Railroad of Georgia and the Atlantic Coast Line, has been an inspiring protagonist of the South's nonmetallic mineral wealth. The state universities have also helped and Departments of Ceramic Engineering were established at North Carolina State and Georgia Tech, and later at Missouri, Alabama, Virginia Polytech, West Virginia, and Oklahoma. North Carolina soon became the largest producer of feldspar. Georgia's kaolins and fuller's earth, Mississippi's ball clays, Oklahoma and Georgia's glass, and Tennessee and Oklahoma's gypsum became prominent commodities.<sup>74</sup> In 1929 a merger created the largest feldspar operation in the country, the United Feldspar Corporation, combining Tennessee Mineral Products Corporation, Oxford Mining & Milling Company, Perham Crystal Feldspar Mines, and United States Feldspar Corporation, with Roessler & Hasslacher as selling agents.<sup>75</sup> Chemically, the introduction of zirconium oxide as an opacifying agent was a significant by-product development growing out of the production of titanium dioxide as a pigment. Cheaper than tin oxide, it was put on the market by the Titanium Alloy Manufacturing Company in 1924, under the trade name Opax.<sup>76</sup>

On the other hand, another famous Southern raw material, tanning extract, declined during the twenties, due to ravages of the chestnut blight. With a large war surplus, leather-tanning activity was very torpid until 1927, when sudden revival revealed the gravity of the blight situation.<sup>77</sup> Dependence upon imported tanstuffs became inevitable † and the use of syntans was promoted so that in 1926 the Bureau of Standards, having been investigating chemical tanning agents for ten years, reported that they entered into a true chemical combination with the tanned hide.<sup>78</sup> Repercussion from these changes was sharp: in 1928, with the closing of its Cass plant, the West Virginia Pulp & Paper Company withdrew from the manufacture of tanning extracts and shortly

\* Born in Baltimore, 1883, Maynard has been a consulting geol. in Atlanta since 1912, and holds many pats. on clay vitrified products, granules for roofing, recovery of potash from shales, manufacture of magnesia and other chemicals from dolomite. He is a fellow, Geol. Soc. Am. and Paleontol. Soc. Am.

† In 1927 the American Dyewood Co. chartered the *S. S. Mumardan* to bring a cargo of 6,000 tons of quebracho wood from Buenos Aires to its Mobile plant. [See *Chem. Mkts.* 20, 798 (1927).]

two of the old extract producers, J. H. Heald Company and Chilhowee Company consolidated their structure and strengthened their finances by incorporating for \$6,500,000 and \$1,800,000, respectively.<sup>79</sup>

The research idea had sparked early in the tanning industry, and in 1920 a cooperative project had been established at the University of Cincinnati under the direction of Dr. George D. McLaughlin. In 1923 the Tanners' Council of America voted \$100,000 for the building of a leather research laboratory at Cincinnati and \$1,250,000 for a three-years' advertising campaign.<sup>80</sup> Four years later Fraser M. Moffat, the president, proposed a \$1,000,000 endowment fund to place this research upon a permanent basis, quite independent of control by any trade organization.<sup>81</sup> That same year Dr. McLaughlin and his associates found that methylamines were powerful dehairing agents, and the Bureau of Standards sought tanning agents to replace natural extracts in sulfite waste liquors from the paper mills.<sup>82</sup>

Similar ideas inspired the Association of American Soap & Glycerin Producers to organize the Cleanliness Institute in 1927 and to sponsor cooperative researches at the Mellon Institute. Its educational organ was the *Cleanliness Journal*.<sup>83</sup> This period is most notable for the discovery of sulfated alcohols, the first so-called soapless soaps. In 1923 it was observed that monoethanolamine reacted with stearic and oleic acids to form soaplike compounds.<sup>84</sup> In 1928 Carbide and Carbon Chemicals Corporation announced through the trade papers that the ethanolamines were available commercially and that their soaps were excellent emulsifiers for all oils, useful also as detergents, as thickeners for lubricants, and in dry cleaning.<sup>85</sup>

Deep-rooted, popular prejudices make the food industries chary of acknowledging any indebtedness to chemistry or chemical products,\* and yet during the 1920's there was a great advance in "chemicalization." The packing houses, notably Armour & Company, led the way by adopting chemical research, but this was chiefly to the end of most profitably salvaging their by-products. At Van Camp Packing in Indianapolis, however, research under the guidance of Dr. George A. Fisher,† took a new turn, applying chemistry not only to production of ready-to-serve foods, but also to exhaustive studies in dietetics and nutrition, even including analysis and biological assays.<sup>86</sup>

This period also saw great progress in the carbohydrates, with the development of several new sugars and starches. The Louisiana cane

\* For a capital summary, see the symposium in *Ind. Eng. Chem.* 20, 1286-1327 (1928). The consumption of chemicals in the foodstuffs field is vastly greater than would be suspected. The 1927 estimates are shown in Appendix XLVIII.

† Dir. research at Van Camp since 1912, Fisher went into private consulting practice in 1935. He was born in Pa. in 1890 and got a Ph.C. and D.Pharm. from Medico-Chemurgical Coll. in Phila., in 1911 and 1914, respectively.



ROBERT I. WISHNICK



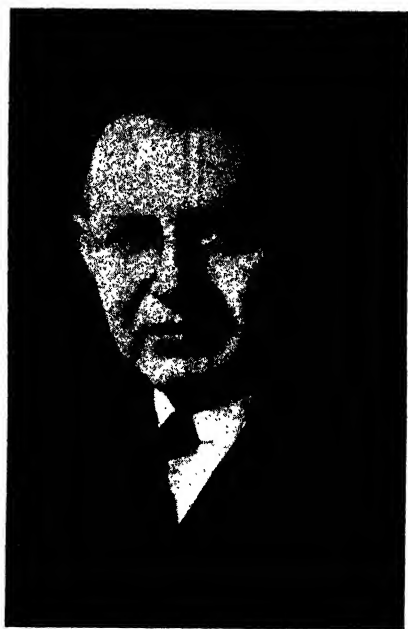
POOLE MAYNARD



OSCAR NELSON



EDWARD R. BERRY



WILLIAM B. NEWKIRK



GEORGE D. McLAUGHLIN



GUY C. HOWARD



*Chemical & Metallurgical Engineering*

ALLEN ABRAMS

mills moved from raw sugar production to complete refining,<sup>87</sup> and the Western beet sugar\* industry, through scientific methods in field and plant, stepped up production from an early 300 pounds of commercial sugar per acre to 3,600 pounds.<sup>88</sup> The first plant employing the invertase method of manufacturing cane sugar sirup came into operation in 1923 at Lufkin, Texas, with a capacity of 5,000 gallons daily.<sup>89</sup> It was a cooperative effort backed by owners of several small sirup mills, under the supervision of H. S. Paine of the Carbohydrate Laboratory of the Bureau of Chemistry. A little later sugar inverted by mild acidulation was put on the market and aggressively pushed to the confectionary and pharmaceutical trades under the trade name of Nulomoline.<sup>90</sup> Dextrose, which had been recovered from glucose during the sugar shortage of the First World War, became a commercial project about 1923, due to improved crystallization methods discovered<sup>91</sup> at the Corn Products Refining Company, by William B. Newkirk.† By 1926 the output of crystallized dextrose reached 500,000 pounds a day, accounting for approximately 6,500,000 bushels of corn annually in the plants of the Clinton Corn Syrup Refining Company, American Maize-Products, Penick & Ford, and Corn Products Refining Company.<sup>92</sup> The Bureau of Standards did much research on rare sugars at this time, working out a process of recovering inulin from chicory and artichokes and converting it into fructose by acidulation.<sup>93</sup> It also cooperated in researches backed by the Federal Phosphorus Company at the University of Alabama and Alabama Polytechnic Institute, which led to the building of a semi-pilot plant at Anniston for the production of xylose, a five-carbon sugar, from cottonseed bran and peanut hulls.<sup>94</sup> The recovery of xylose from cornstalks and levulose from artichokes was also accomplished at this time, and O. E. May and H. T. Herrick of the Bureau of Chemistry and Soils found a penicillium which fermented dextrose solutions to gluconic acid.<sup>95</sup> In 1927 the A. E. Staley Manufacturing Company, established in 1897 at Decatur, Illinois, entirely rebuilt its plant.<sup>96</sup> By the close of the period 11 American companies were manufacturing various corn products, using some 85,000,000 bushels, a third of the crop that reached the open market.<sup>97</sup>

Ricocheting from the Prohibition Law which made by-product alcohol from yeast production a liability, the Fleischmann Company worked

\* Dr. Joseph H. Hirsh, who died in 1930, was credited with the discovery of recovering sugar from beets during the Civil War, for which he was awarded the medal of the American Institute of N. Y.

† U. S. Pats. 1,471,347 (1923); 1,640,717 (1927). Twice chmn., Sugar Div., Am. Chem. Soc., and head of the Tech. Advisory Comm., Corn Ind. Research Found., Newkirk was with American Alcohol, Federal Chemical, American Beet Sugar, and the Bur. Standards, before going with Corn Products Refining in 1919. He was trained in chem. at U. So. Calif., A.B., 1910.

out a process without the production of ethanol,<sup>98</sup> for yeast was rapidly acquiring new values as a source of vitamin B. Exploitation of these medicinal uses was further encouraged by an oversupply of yeast, since the bakery industry had learned that a mixture of malt sirup, ammonium chloride, a calcium salt, and an oxidizing agent added to dough cut down the yeast requirement 50 per cent,<sup>99</sup> and although vitamin- and mineral-enriched bread had at the time a brief and uncertain career, it was actually on the market as early as 1923.<sup>100</sup> In the allied baking powder\* field there were some company changes. In 1927 the Rumford Chemical Works, abandoning the 40-year old Providence plant, moved to a new building in Rumford, Rhode Island, and the following year transferred there the operations of the subsidiary Layton Pure Food Company of St. Louis, which had been acquired in 1920.<sup>101</sup> Royal Baking Powder and Fleischmann merged as Standard Brands, Inc., in 1929, when the former sold to its stockholders its interest in the American Maize-Products Company which thereafter became an independent organization.<sup>102</sup> In the same vein, United Chemicals bought 97 per cent of the outstanding stock of its subsidiary, the Monarch Chemical Company, manufacturers of the Monarch Cream and Majestic brands of baking powder.<sup>103</sup>

The nutrient values of gelatin were tested at the Mellon Institute,<sup>104</sup> and its Japanese rival, agar-agar, was made in the United States from Pacific Coast seaweed for the first time in 1927, by the American Agar Company in San Diego, California.<sup>105</sup> Pectin from waste-fruit pulps, an American development, became available commercially in both the powder and liquid forms, in wide ranges of jellifying power, from firms in New York, Illinois, Missouri, Oregon, Florida, and California.<sup>106</sup> In 1925 Jacques Wolf & Company opened a new department to produce seaweed products for the food and drug industries.<sup>107</sup> Algin from kelp was commercially produced in pure form by Thornley & Company, San Diego, California, and later in 1928 at Los Angeles the Tanner Kelp Products Company and Phillip R. Park Company cooperated in building a kelp plant in which Park produced stock food and Tanner extracted algin, iodine, poultry feed, and lacquer bases.<sup>108</sup> Two unusual and exceptionally profitable researches of the period were carried on at the New Jersey College of Pharmacy and the Mellon Institute. At the former, the Kraft Research Fellowship, headed by Dr. Lloyd K. Riggs,† developed new types of cheeses of increased food value,<sup>109</sup> while at Mellon the Food Container Fellowship, after almost ten years'

\* See also Chap. 7.

† Riggs became dir. research, Kraft Cheese Co., in 1936, having been prof. physiol., N. J. Coll. Pharm., Rutgers, since 1926 and before that with Squibb. He was born in Iowa, 1888, and got his Ph.D. from U. Chicago in 1918.

continuous investigation in 1926 perfected<sup>110</sup> an edible synthetic (viscose) substitute for the animal sausage casings.\* In the middle twenties, after years of trial and error, frozen foods became practical, when Clarence Birdseye perfected his "double-belt froster" embodying the advantages of packaging first and freezing afterwards.<sup>111</sup> In 1929 the Birdseye process was purchased by General Foods Corporation through its subsidiary, the Postum Company.<sup>112</sup>

Mechanical refrigeration was also coming rapidly into prominence. It received a fillip in the early 1920's when it was adapted, chiefly by the Nizer Corporation, to ice-cream cabinets in soda fountains.<sup>113</sup> Installations continued to be chiefly industrial, but definite starts were made toward the household field. Significantly, a number of new refrigerants appeared and by 1929 about 40 firms were manufacturing refrigerating machines using ammonia; 10 using carbon dioxide, all large-capacity units for commercial refrigeration; about 30, methyl chloride, almost entirely for household units; 30 to 40, sulfur dioxide; 1, air; 2, water; 1, isobutane; and a few small, unimportant models employing various other refrigerants usually under trade names.<sup>114</sup> Ammonia, used for over half a century, had shown little increase from the approximately 2,000,000 pounds applied in refrigeration in 1914. Sulfur dioxide, in commercial use as a refrigerant since 1910, continued to be the sole refrigerant in domestic units until about 1922; its use increased enormously from 100,000 pounds in 1922 to over 5,000,000 in 1929. Methyl chloride,† which only became available from a domestic manufacturer in this country after 1920, from Roessler & Hasslacher, increased rapidly in popularity, reaching a consumption of approximately 1,000,000 pounds in 1929. Ethyl chloride and various petroleum hydrocarbons such as isobutane, ethane, and propane, involved a fire hazard which confined them strictly to industrial installations. Experiments were already afoot with the use of carbon tetrachloride, dichloromethane, dichloroethylene, and trichloroethylene, forecasting Midgley's discovery of dichlorodifluoromethane, shortly to be commercialized by du Pont under the trade name of Freon.

Solid carbon dioxide, soon popularly identified as "dry ice," came into the limelight and promptly reached the patent courts.‡ Ton lots were produced by the Pennsylvania Sugar Company in 1922, it is claimed

\* See Chap. 21.

† Discovered by Péligot and Dumas in 1835, methyl chloride's first application was a methylating agent in dyemaking. Commercially manufactured in 1874, it was used as a refrigerant abroad in 1895 and approved by the French Navy for submarines. [See J. B. Churchill, *Ind. Eng. Chem.* 24, 623 (1932).]

‡ The earliest patents on CO<sub>2</sub> as a refrigerant were taken out by a British army doctor, Herbert S. Elworthy, who when stationed in India, solidified CO<sub>2</sub> to keep Vichy cold for whisky and soda.



by Gustave T. Reich.\* But it was 1925 before carbon dioxide was available generally from the Prest-Air Devices Company, which had been organized in 1922 to develop the patents of Thomas Benton Slate,† promoted by W. L. Josephson, and backed by August Heckscher. They formed the DryIce Corporation, which made arrangements with the Liquid Carbonic Corporation of Chicago to supply carbon dioxide for compressing. A series of 17 plants on a coast-to-coast setup was established and production by 1929 reached 14,000 tons.<sup>115</sup> Though initially dry ice sold for from 10 to 20 times the price of water ice per unit of refrigeration, it was soon manifest that economical production depended upon cheap by-product carbon dioxide from fermentation, lime kilns, chemical processes, and various other sources.<sup>116</sup> Upon this basis du Pont built a plant in 1928 in conjunction with its Eastern Alcohol operation at Deepwater, New Jersey.<sup>117</sup> Despite the patent litigation, a number of sizable companies were organized: Solid Carbonic Company, Ltd., incorporated in Delaware in 1927; Carbon Dioxide & Chemical Company, also a Delaware corporation, 1929; and that same year, Solid Dioxide Corporation.<sup>118</sup> While its refrigeration uses were thus vigorously exploited, carbon dioxide was found to be an excellent fire extinguisher, a promising application that developed importantly in the next decade.<sup>119</sup>

\* Reich came to U. S. in 1912, after receiving his Ph.D. from Berlin, and became chem. for the Norton Co. He was chief research chem. for Hooker Electrochemical, 1914-17, and later with Great Western Electro-Chemical, Mason By-Products, Crystal Chemical, and consulting chem., before joining Penn. Sugar in 1928. [See his article, *Chem. Met. Eng.* 38, 270 (1931).]

† Slate, who spent many years in the oil and natural gas areas of the Southwest, invented many uses for CO<sub>2</sub> in the home, including a fire extinguisher, siphon for beverages, tire pump, and grease gun. (See *Fortune* 75, July 1932.)

## REFERENCES

1. *Rubber Age* (N. Y.) 21, 165 (1927); E. A. Hauser, to author, Feb. 24, 1947.
2. W. C. Geer, *Annual Survey of American Chemistry* (1926-27), II, 390.
3. Co. memo to author.
4. J. B. Garner, *Chem. Ind.* 44, 631 (1939); Haynes, *This Chemical Age*, p. 222.
5. Tariff Comm., *Census of Dyes*, 1926, p. 23; J. W. Kinsman, *Chem. Met. Eng.* 33, 35 (1926); G. Oenslager, *Ind. Eng. Chem.* 18, 903 (1926).
6. I. du Pont, *Ind. Eng. Chem.* 18, 1003 (1926).
7. *Drug Chem. Mkts.* 13, 421, 1458 (1923); *Chem. Met. Eng.* 29, 192 (1923).
8. G. D. Kratz, A. H. Fowler, and C. Coolidge, *J. Ind. Eng. Chem.* 12, 317 (1920).
9. A. W. Deller, *ibid.* 20, 1361 (1928); *Drug Chem. Mkts.* 17, 1193 (1925); *Chem. Mkts.* 19, 1365 (1926); *Chem. Met. Eng.* 33, 105 (1926).
10. *Chem. Mkts.* 22, 530 (1928).
11. *Drug Chem. Mkts.* 17, 1193 (1925).
12. D. H. Killeffer, *Ind. Eng. Chem.* 18, 1044 (1926).
13. O.P.D. *Reptr.* 50 (Mar. 28, 1927); *Chem. Mkts.* 20, 491 (1927); *Chem. Met. Eng.* 34, 121 (1927).
14. F. Talbot and W. N. Watson, *Ind. Eng. Chem.* 21, 9 (1929); *Chem. Mkts.* 22, 495 (1928).

15. *Chem. Mkts.* 20, 621 (1927); *O.P.D. Reprtr.* 46 (Nov. 4, 1929).
16. Killeffer, *op. cit.*; N. A. Shepard, *Ind. Eng. Chem.* 25, 35 (1933); P. I. Murrill, *ibid.*, *News Ed.* 20, 1361 (1942).
17. *Drug Chem. Mkts.* 18, 1009 (1926); *Chem. Mkts.* 21, 497 (1927).
18. For latest techniques and applications, see Noble, *Latex in Industry*; Hauser, *Latex*, Chap. 12; Marchionna, *Latex and Its Industrial Applications*.
19. *Chem. Met. Eng.* 28, 127 (1923); *Drug Chem. Mkts.* 14, 114 (1924).
20. W. L. Semon, *Ind. Eng. Chem., News Ed.* 21, 1613 (1943).
21. *Ind. Eng. Chem.* 17, 711 (1925).
22. Killeffer, *ibid.* 19, 1078 (1927); *Fortune* 65 (June 1940); Semon, *op. cit.*
23. Oenslager, *op. cit.*
24. Semon, *op. cit.*; *Chem. Met. Eng.* 33, \*253 (1926).
25. Semon, *op. cit.*; *Fortune*, *op. cit.*; Haynes and Hauser, *Rationed Rubber*, p. 129.
26. *India Rubber World* 75, 1435 (1926).
27. Co. memo to author.
28. *Ibid.*; see also *India Rubber World* 65, 282 (1922), R. L. Sibley, *Ind. Eng. Chem.* 22, 552 (1930).
29. *Chem. Mkts.* 20, 865 (1927).
30. C. M. Kolb, Hearings, Sched. 1, June 1929, p. 342.
31. *Chem. Mkts.* 19, 1291 (1926); *Chem. Met. Eng.* 34, 332 (1927); R. L. Carr, to author, Mar. 3, 1947.
32. Carr, *op. cit.*
33. *Drug Chem. Mkts.* 18, 551 (1926); *Chem. Mkts.* 21, 289 (1927); General Atlas Carbon Co. memo to author.
34. Interchemical Corp. memo to author.
35. *Drug Chem. Mkts.* 18, 1152 (1926).
36. *Ibid.* 12, 1045 (1923).
37. *Chem. Mkts.* 19, 701 (1926); 20, 310, 489 (1927).
38. *Moody's Manual of Investments, Industrials*, 1940; *O.P.D. Reprtr.* 29 (Jan. 26, 1925); *Drug Chem. Mkts.* 16, 265 (1925).
39. A. G. Treadgold, to author, Mar. 19, 1945.
40. Co. memo to author.
41. *Ibid.*; *Chem. Mkts.* 20, 331 (1927).
42. W. F. Twombly, to author, Mar. 13, 1947.
43. *Drug Chem. Mkts.* 16, 275 (1925).
44. *O.P.D. Reprtr.* 20 (Dec. 9, 1929).
45. W. J. Baxter, *Rayon* 7 (Oct. 27, 1925); *Drug Chem. Mkts.* 17, 1263 (1925).
46. Baxter, *Rayon* 8 (Oct. 27, 1925); 9 (Nov. 30, 1925).
47. *Ind. Eng. Chem., News Ed.* 12 (Sept. 20, 1927).
48. *Chem. Mkts.* 23, 51 (1928).
49. J. S. Reichert, *Ind. Eng. Chem., News Ed.* 21, 480 (1943).
50. *O.P.D. Reprtr.* 38 (June 28, 1926).
51. *Ibid.* 16 (Nov. 12, 1928).
52. *Ind. Eng. Chem.* 19, 767 (1927).
53. *Rayon* 35 (Dec. 1, 1928).
54. Tariff Comm., *Census of Dyes*, 1926, p. 49.
55. *Fortune* 112 (July 1937).
56. H. O. Moraw, *Chem. Mkts.* 27, 153 (1930).
57. H. J. Skinner, *Ind. Eng. Chem.* 24, 697 (1932), 30, 318 (1938); H. R. Murdock, *Chem. Met. Eng.* 44, 4 (1937); J. A. Lee, *ibid.* 432.
58. Co. memo to author.
59. J. D. Rue, and others, *Chem. Met. Eng.* 34, 611 (1927); bibl. in Rue, *Paper Trade J.* 81, No. 16, 57 (1925).
60. E. O. Rhodes, *Ind. Eng. Chem.* 31, 556 (1939).
61. R. J. Quinn, *Chem. Mkts.* 29, 253 (1931).
62. H. A. Johnson, *Chem. Met. Eng.* 33, 732 (1926); see also Borth, *Pioneers of Plenty*, p. 130; Haynes, *Southern Horizons*, p. 162; McMillen, *New Riches from the Soil*, p. 228.
63. *Chem. Met. Eng.* 34, 390, 399 (1927); *Chem. Mkts.* 21, 74 (1927).
64. *Chem. Mkts.* 23, 52 (1928).
65. A. Silverman, *Ind. Eng. Chem.* 18, 898 (1926); *Ann. Druggist*, 58 (Dec. 1926); *Fortune* 71 (Feb. 1930).
66. *Chem. Met. Eng.* 29, 307, 1116 (1923).
67. *O.P.D. Reprtr.* 62 (Apr. 1, 1929); *Drug. Circ.* 72 (May 1929).
68. H. S. Wherrett, *Chem. Ind.* 48, 303 (1941); *Glass Ind.* 3, 209 (1922).
69. *O.P.D. Reprtr.* 21 (Dec. 7, 1925).
70. Killeffer, *Ind. Eng. Chem.* 16, 995 (1924); E. R. Berry, *Chem. Met. Eng.* 30, 715 (1924); R. S. Hutton, *Trans. Am. Electrochem. Soc.* 51, 49 (1927).
71. J. F. Walsh, *Chem. Met. Eng.* 37, 418 (1930); W. L. Morgan, *Ind. Eng. Chem.* 23, 505 (1931); *Moody's Man-*

- ual, *op. cit.* 1944, p. 1805.
72. *Min. Ind.* 1927, 56.
  73. *Chem. Mkts.* 23, 582 (1928).
  74. A. F. Greaves-Walker, *Chem. Met. Eng.* 41, 26 (1934); *Min. Ind.* 1923, 242.
  75. *Chem. Mkts.* 25, 71 (1929).
  76. *Min. Ind.* 1925, 707; 1926, 680.
  77. Tariff Comm., *Ann. Rept.* 1921, quoted in *Drug Chem. Mkts.* 10, 739 (1922); *Chem. Mkts.* 19, 818 (1926), 20, 366 (1927).
  78. *Drug Chem. Mkts.* 18, 751 (1926).
  79. West Virginia Pulp & Paper Co. memo to author; *Chem. Mkts.* 23, 372 (1928), 24, 623 (1929).
  80. *Drug Chem. Mkts.* 12, 1175 (1923).
  81. *Chem. Mkts.* 20, 910 (1927); *Chem. Met. Eng.* 34, 641 (1927).
  82. E. H. Riddle, *Chem. Ind.* 56, 209 (1944); *O.P.D. Repr.* 20 (May 23, 1927), orig., E. L. Wallace and R. C. Bowker, *Bur. Stand., Tech. Paper No. 339* (1927).
  83. *Chem. Mkts.* 21, 366 (1927).
  84. R. Koganei, *J. Biochem. (Japan)* 3, 19 (1924).
  85. *Chem. Mkts.* 23, 285 (1928); A. L. Wilson, *Ind. Eng. Chem.* 22, 143 (1930); R. B. Trusler, *ibid.* 21, 685 (1929).
  86. *Ind. Eng. Chem., News Ed.* 9, 52 (1931).
  87. H. A. Levey, *Chem. Met. Eng.* 39, 404 (1932).
  88. *Drug. Circ.* 10 (Feb. 1926); *Chem. Mkts.* 26, 293 (1930).
  89. *Ind. Eng. Chem., News Ed.* 3 (June 10, 1923).
  90. *Chemist & Druggist* 106, 675 (1927).
  91. W. B. Newkirk, *Ind. Eng. Chem.* 31, 156 (1939); *Pharm. Era* 60, 459 (1925).
  92. *Chem. Met. Eng.* 33, 101 (1926).
  93. *Drug. Circ.* 12 (Apr. 1929).
  94. *Chem. Met. Eng.* 35, 770 (1928), 37, 97 (1930); W. E. Emley, *ibid.* 37, 283 (1930); *Chem. Mkts.* 24, 60 (1929). For tech. details of process, see W. T. Schreiber, and others, *Ind. Eng. Chem.* 22, 497 (1930).
  95. *Am. Druggist* 17 (Mar. 1925); *Chem. Met. Eng.* 34, 774 (1927), 36, 665 (1929); *O.P.D. Repr.* 58 (May 20, 1929); May, Herrick, and others, *Ind. Eng. Chem.* 21, 1198 (1929).
  96. *Chem. Met. Eng.* 34, 464 (1927).
  97. T. P. Walker, *Chem. Mkts.* 24, 484 (1929).
  98. Hearings Ways & Means Comm. (House 70:2) on Tariff Readjustment, Sched. 5, Jan. 22, 1929, p. 2436.
  99. G. D. Beal, *J. Am. Pharm. Assoc.* 17, 600 (1928).
  100. C. Hoffman, *Ind. Eng. Chem.* 15, 1225 (1923).
  101. Co. memo to author; *Chem. Mkts.* 21, 200 (1927); *Chem. Met. Eng.* 34, 528 (1927).
  102. Co. memo to author.
  103. *Con. Fin. Chron.* 129, 817 (1929); see also Chap. 8.
  104. Beal and A. Neff, *J. Am. Pharm. Assoc.* 17, 261 (1928).
  105. H. D. Mackinnon, *Drug Mkts.* 24, 552 (1929); for processing, see *Chem. Met. Eng.* 34, 294 (1927).
  106. California Citrus League, Hearings Ways & Means Comm., *op. cit.* Sched. 1, Jan. 7, 1929, p. 74.
  107. Co. memo to author.
  108. *Chem. Met. Eng.* 35, 360 (1928); *O.P.D. Repr.* 38 (Feb. 13, 1928).
  109. *Drug. Circ.* 10 (May 1930).
  110. *Am. Druggist* 39 (Dec. 1926); *Chem. Met. Eng.* 44, 551 (1939).
  111. C. Birdseye, *Trans. Am. Inst. Chem. Engrs.* 26, 249 (1931).
  112. *Ind. Eng. Chem., News Ed.* 9, 9 (1931).
  113. *Drug. Circ.* 70, 464 (1926).
  114. J. B. Churchill, *Chem. Mkts.* 25, 587 (1929).
  115. *Chem. Met. Eng.* 34, 783 (1927), 35, 777 (1928); H. E. Howe, *Ind. Eng. Chem.* 20, 1091 (1928); Killeffer, *ibid.* 18, 1043 (1926), 19, 192 (1927), 22, 1087 (1930); *Fortune* 74 (July 1932); Quinn and Jones, *Carbon Dioxide*, p. 193.
  116. C. L. Jones, *Chem. Met. Eng.* 37, 416 (1930).
  117. *Chem. Mkts.* 22, 356 (1928).
  118. *Ibid.* 21, 328, 859 (1927), 25, 512, 617 (1929); Killeffer, *Ind. Eng. Chem.* 19, 1080 (1927).
  119. Killeffer, *Ind. Eng. Chem.* 19, 1080 (1927).

## Chapter 26

### BROADENING CHEMICAL BOUNDARIES

NEW RAW MATERIALS, TONNAGE SYNTHETICS, NEW USES EXPAND CHEMICAL INDUSTRY—NATIONAL RESEARCH COUNCIL LEADS COOPERATIVE ACADEMIC-INDUSTRIAL RESEARCH—WILLIAMSTOWN SYMPOSIUM ON CHEMISTRY IN WORLD AFFAIRS—AMERICAN CHEMICAL SOCIETY SPONSORS INSTITUTE OF CHEMISTRY—GIFTS FURTHER CHEMICAL EDUCATION, BUILD UNIVERSITY LABORATORIES—AMERICAN INSTITUTE OF CHEMISTS AND ASSOCIATION OF CONSULTING CHEMISTS & CHEMICAL ENGINEERS ORGANIZED—CHEMICAL EXPOSITION AND CHEMICAL TRADE PAPERS REVAMPED.

THE CHEMICAL REALM EXTENDED during the 1920's upwards, downwards, and on all sides. New raw materials—petroleum, natural gas, cellulose, corn, fatty acids, rosin and turpentine, even the atmosphere—were all energetically exploited, and significantly, vast organic enterprises, not based on coal tar, sprang up and prospered. Acetylene and ethylene became the bases of new chemical industries, and even coal tar achieved a new commercial status when phenol and phthalic anhydride began moving into plastics and synthetic resins in incredible quantities.<sup>1</sup> Tonnage chemicals from synthetic processes—ammonia, methanol, and acetic acid—appeared and chemicals new to commerce—butanol, aluminum chloride, and ethylene glycol—became important products. New uses of chemicals created unsuspected markets.

Simultaneously the techniques of chemical production were improved by applying higher pressures and higher temperatures, more efficient catalysts and continuous processes. As a result, the chemical industry enjoyed the only true and lasting benefits of real economic progress, cheaper and more abundant production.

This twofold chemical advance wrought a chemical revolution in American industry.\* Herein lay the great chemical events of the aftermath of the First World War. It was the broad advance of chemical technology expressed tangibly in the wide commercial acceptance of chemically made materials that determined the future course of chemical manufacturing in the United States.

Except for prompt realization that these broader uses of chemical

\* For review of the postwar progress in the chemical and allied industries, see E. R. Weidlein, *Chem. Met. Eng.* 34, 209 (1927), A. H. Swift, *Ind. Eng. Chem.* 20, 657 (1928), O. Wilson, *ibid.* 24, 388 (1932), 25, 104 (1933); for statistics, 1923-29, Appendix I.

products opened undreamed-of outlets of apparently boundless consuming capacity, even the chemical industry itself did not recognize the revolutionary character of its products. Manufacturers of textiles, rubber goods, coatings, fertilizers, insecticides, metalwares, medicines, and a host of other consuming goods, were severely jolted by the new chemical materials and chemical methods, but nobody then appreciated that a profoundly disturbing, powerfully stimulating element had been thrust into the American industrial system. Within the next twenty years the remotest corner of American industry was to feel the impact of these chemical repercussions. Their effects on the chemical industry were immediate and very forceful.

Nowhere were these effects more impressive than in the laboratories where research shouldered the added responsibility of finding uses for new chemicals. This soon led to research deliberately aimed at creating new chemicals that would more cheaply and more efficiently perform definite tasks. Furthermore, the scientific spirit and the tools of scientific investigation were extended into the commercial field where technical service to customers became the rule, not the exception. Such expert advice was quite necessary in the introduction of new products, but it proved to be so valuable a sales aid and such a builder of good will that it soon became standard practice.

A sign of the times was the exodus of chemical company New York offices from their traditional center in lower Manhattan. Partly this expressed greater concern for visiting customers, but also the demand for downtown office space advanced rents till it was profitable for industrial firms to move uptown. The Grand Central section became chemical headquarters, though later many firms moved to Rockefeller Center. At the same time, drug and pharmaceutical firms began congregating in the middle West Side, along Varick and Hudson Streets. The migration from the austere atmosphere of "Downtown" to the "Roaring Forties" begat luxurious habits,\* which one of the trade papers<sup>2</sup> described with good-natured sarcasm: "The walnut desk in paneled office; the intricate statistical and record-keeping machinery; the reception clerks, engraved stationery, and private secretaries for all but the cub salesman who covers Hoboken and Weehawken." The uptown movement also forced many executives to change their allegiance from the Drug and Chemical Club on John Street to the Chemists' Club on East 41st Street, so that the downtown organization

\* Unique among the new offices were those of the Chemical Foundation and the Hooker Electrochemical Co., furnished by Francis P. Garvan and Elon H. Hooker with authentic American antiques. Both men were avid collectors, and Hooker once said that his company was the only one whose office furniture showed no depreciation, but a steady annual appreciation of book value.

became more than ever the rendezvous of insurance men,\* while the Chemists' Club became less exclusively the headquarters of professional chemists and engineers.†

These were but the superficialities of the postwar changes that so profoundly affected research. Prior to the First World War research in the American chemical industry was mainly directed toward the improvement of plant processes with the object of lowering costs. Until many needed chemicals were cut off by hostilities there was little development of new compounds, and the war effort was aimed to fill these immediate wants. Nevertheless most of these war-famine chemicals had never before been made in America. After the war, with surplus stocks and a great excess of productive capacity, research of necessity took a new turn, the search for new products—now really new compounds—as the natural means of relieving the competitive pressure. The hunt for new uses, the third great objective of organized research, followed inevitably.

Research activities teemed in every branch of chemistry and, as we have seen, boiled over into the allied fields where chemical processing is a prominent part of the manufacturing operation. Emulating the example of the tanners and the papermakers, even producers of raw materials embarked on cooperative research, and most surprisingly, the pioneer investigations of new uses for natural raw materials were backed by men of semi-agricultural industries in the South, naval stores and cottonseed.‡

That science hitched to the industrial applecart would carry this country to a new economic plane with universal prosperity rising year after year to higher and higher levels, became the first principle of the effervescent credo of the day. Research became almost a fetish and in this surge of popularity it was adopted by many who knew nothing of

\* In the "Drug Club," which rivals the India House as having the best kitchen of any of New York's many business luncheon clubs, the friendly conflict of drug and insurance interests dates back to the 1890's when the members of a struggling insurance organization were taken in bodily. The explanation—of the chemical men—always was that insurance men could never have a club of their own, because it was a waste of time to take another insurance man to lunch and no sane insurance man would risk taking a client into a den of rivals.

† The Chemists' Club celebrated its 25th anniversary with a dinner at the annual meeting, May 1923, when Floyd J. Metzger was elected pres.; Allen Rogers and E. R. Weidlein, vice-pres.; A. G. Robinson, treas.; H. G. Sidebottom, secy.; and S. A. Goldschmidt and Andrew A. Holmes, trustees. [See *Drug Chem. Mkts.* 12, 1113 (1923).]

‡ The cottonseed research was launched in 1927 by the Interstate Cottonseed Crushers' Assoc. under Dr. Earl P. Clark. It was accompanied by another forward-looking cooperative effort when that same year the Texas Cotton Seed Crushers' Assoc. engaged A. L. Ward as educational dir. and began a campaign (later absorbed by the national organization) advertising cottonseed products. [See *Chem. Met. Eng.* 34, 191 (1927); *Chem. Mkts.* 20, 366 (1927).]

its proper objectives or true functions. Fortunately the time had passed when the misuse of research as fancy window-dressing to impress customers and competitors\* could have any appeal to chemical executives. Although there were still some in the industry who paid only lip service to research, nevertheless the new processes and new products crowding upon the industry during the postwar decade demonstrated that research was quite as vital a part of the business as accounting or sales.

Throughout all branches of chemistry, cooperative activities—researches, publications, symposiums, conferences, and prize awards—multiplied during the 1920's. A fountainhead of such projects was the National Research Council. One of its most active agencies was the Division of Engineering and Industrial Research of which Maurice Holland became director in 1923. In 1928 the Council appointed a special committee to foster cooperative research between the industries and the academic institutions, with Dr. William J. Hale, past chairman of the Division of Chemistry and Chemical Technology, as chairman.<sup>3</sup> This Division has sponsored the *Annual Survey of American Chemistry*. The first volume appeared in 1926 under Dr. Hale's editorship, assisted by Clarence J. West, who became editor with the second volume, continuing until its suspension with Volume X in 1935. In the first issue of this useful and lamented publication, Dr. Hale submitted a carefully drawn report on cooperative research. He outlined standard practice as to reasonable objectives, proper stipends, and individual responsibilities of the companies and universities, which greatly furthered this fruitful type of work. Even more important was the publication by the Council of *International Critical Tables* in 1926. The original suggestion for this compilation of chemical and physical constants had been made at the London meeting of the International Union of Pure and Applied Chemistry in 1919, and the National Research Council had undertaken this important task, which was started under three trustees: Hugh K. Moore, representing the Council; Julius Stieglitz, appointed by the American Chemical Society; and Edward P. Hyde, named from the American Physical Society.<sup>4</sup> Later George P. Adamson of General Chemical became chairman, and to the original trustees were added Harrison E. Howe, editor of *Industrial & Engineering Chemistry*;

\* Flagrant misuse of the very word "research" started in the 1920's when advertising agencies began labeling any fact-finding job a "research project." The word's meaning has since been stretched in many directions. Today (1947) a "researcher" may be anyone from a reporter on a news magazine to the statistician of a farm implement manufacturing company, while "research activities" range from a house-to-house canvas of lipstick users to compiling a mailing list from telephone books. These are not funny exaggerations but actual examples indicating that soon a new word will have to be coined to distinguish the accumulation or verification of facts, which is "search," from the true "research," which is the discovery of unknown facts. (W. H.)

Charles L. Reese of du Pont; and William M. Corse of the National Research Council, secretary.<sup>5</sup>

Conferences and symposiums, such as we have come to know as "refresher courses," were exceedingly popular at this time. The most ambitious was the Williamstown Institute of Politics, engineered by the energetic president of Williams College, Dr. Harry A. Garfield. Its session of 1926 was devoted to chemistry in world affairs. An international flavor was provided by the illustrious Scotch chemist, Sir James Irvine of the University of St. Andrews; by the Italian electrochemical manufacturer, Umberto Pomilio; and the French maker of synthetic aromatics, Justin Dupont.<sup>6</sup> Round-table discussions were conducted by Harrison E. Howe on chemistry in world affairs, by Charles K. Leith on the world's mineral resources, and by Charles H. MacDowell on fertilizers.\*

The following year, 1927, the useful but short-lived Institute of Chemistry, sponsored by the American Chemical Society,<sup>†</sup> was inaugurated at the Pennsylvania State College. The underlying purpose of the sessions, which lasted throughout July under the general chairmanship of Dr. Gerald L. Wendt, was to furnish contact between teachers of chemistry and men in the industry who were actively applying chemistry. At the opening meeting the economic factors of chemical production were discussed by John Teeple, Charles H. Herty, and Williams Haynes. Thereafter such specific subjects as catalysts, X-rays, organic solvents, lacquers, were discussed in detail, usually by a university faculty member and a practical, operating man from the industry.<sup>7</sup> There were more than 35 speakers, including such distinguished foreign chemists as Jean Piccard, University of Lausanne; Hans Tropsch, then assistant director of the Ruhr Coal Research Institute; B. K. Rideal of Cambridge University; J. C. Drummond of University College in London; while from American industry came such men as A. A. Backus of "U.S.I." and J. G. Davidson of Carbide and Carbon Chemicals, who spoke on organic solvents; Michael Callahan of du Pont, on lacquers; Irving Langmuir of General Electric, on catalysts; Ancel St. John, the consultant, on X-rays.

The importance of the business side of chemistry to chemists was

\* Speakers who led the various group discussions were Roger Adams on synthetics; John E. Teeple on wastes; Williams Haynes of chemical economics; Morgan H. Grace and George R. Mansfield on phosphates; John W. Turrentine and C. C. Concannon on potash; Harry A. Curtis on nitrogen; Walter Aldridge on sulfur; A. D. Ledoux on pyrites; Charles J. Brand on mixed fertilizers.

<sup>†</sup> The Comm. of Direction appointed by Am. Chem. Soc. pres. Geo. D. Rosengarten, consisted of Gerald L. Wendt, School of Chemistry & Physics at Penn. State; Prof. F. C. Whitmore, Northwestern U.; Willis R. Whitney, General Electric; C. M. A. Stine, du Pont; C. E. K. Mees, Eastman Kodak; and Frederic W. Willard, Western Electric. [See *Chem. Met. Eng.* 34, 326 (1927).]



underscored when the American Chemical Society approved\* the organization of a Section of Chemical Economics.<sup>8</sup> At Swampscott in the autumn of 1928 an economic symposium on nitrogen—the first of its kind at any American Chemical Society meeting—was held under the chairmanship of Williams Haynes. It was addressed by Jasper E. Crane, president of Lazote; E. M. Allen, president of Mathieson Alkali; H. R. Bates, production manager of International Agricultural; Charles J. Ramsburg, vice-president of Koppers; and W. S. Landis, vice-president of American Cyanamid.<sup>9</sup>

An example of one of the numerous, highly professional conferences, was the first national Symposium on Colloidal Chemistry at the University of Wisconsin, June 12-15, 1923, fathered by the National Research Council.<sup>10</sup> Colloid chemistry, as Professor H. N. Holmes of Oberlin College pointed out,<sup>11</sup> was receiving great commercial consideration at the time, being applied to de-inking newspapers and the manufacture of soap, glues, gelatins, fruit jellies, lubricants. Jerome Alexander wrote a series of articles on the practical uses of colloidal chemistry for the *Oil, Paint & Drug Reporter*,<sup>12</sup> and du Pont established<sup>13</sup> research on colloids under Elmer O. Kraemer.<sup>†</sup>

In these years of prosperity, chemical education benefited luxuriously from gifts and endowments. The greatest was some \$80,000,000, a legacy from James Duke, which transformed Trinity College, Durham, North Carolina, into Duke University.<sup>14</sup> Arthur H. Fleming gave \$4,000,000 to the California Institute of Technology<sup>15</sup> with the suggestion that it limit its enrollment to 2,000 and that it specialize in chemistry and physics. John D. Larkin, the soap manufacturer, left \$350,000 to the Chemistry Department of the University of Buffalo.<sup>16</sup> Captain Isaac E. Emerson of Bromo-Seltzer, gave \$75,000 for a chair of biological testing and drug assaying at the University of Maryland School of Pharmacy, and to its Medical School, a fellowship in pharmacology amounting to \$1,500 a year.<sup>17</sup> Francis P. Garvan established two scholarships at Vassar and two at Yale.<sup>18</sup> Frederick K. Stearns having already given to the University of Michigan a pharmacology fellowship, funds to establish the Stearns' Botanical Garden, and his collection of musical instruments, the F. Stearns & Company added another fellowship in chemistry in his memory.<sup>19</sup> Four famous university chemical laboratories were built at this time: Sterling Chemistry Laboratory at Yale, with a bequest of \$2,000,000 from John W. Sterling;<sup>20</sup> Mallinckrodt Chemical Laboratories at Harvard, the gift of Edward

\* Though authorized, this Section was never formally organized.

† Kraemer was prof. colloid. chem. at U. Wis., where he earned his Ph.D. in 1924. He studied also at Upsala and the Kaiser Wilhelm Inst. and had held the American-Scandinavian Foundation and Nat. Res. Council fellowships.

Mallinckrodt;<sup>21</sup> Nichols Chemical Building at New York University, the gift of \$600,000 through the Nichols Foundation by Dr. William H. Nichols;<sup>22</sup> and Chandler Laboratories at Columbia by \$1,000,000 raised in memory of the late Professor Charles F. Chandler.<sup>23</sup>

While these rich gifts, in which scores of smaller institutions shared, were raising the physical equipment of American chemical education to the highest point of efficiency, the courses and methods of teaching the science were being overhauled. The American Chemical Society\* took active interest in the modernization of chemical education. As early as 1925 the American Institute of Chemical Engineers began accrediting chemical engineering courses, while the recently organized American Institute of Chemists named<sup>24</sup> a special committee to investigate professional training.† With the fall term of 1923 all schools of pharmacy which were members of the American Conference of Pharmaceutical Faculties, advanced their entrance requirements to a minimum of a four-year high school course, and simultaneously the National Association of Boards of Pharmacy made a like requirement a prerequisite for taking board examinations.<sup>25</sup> Also at the precollege level, the high school teachers of chemistry, working under the American Chemical Society Committee on Chemical Education, and the various state teachers' associations began to harmonize the chemical curriculum to correlate with the college requirements.<sup>26</sup>

Prizes and medals to stimulate and reward outstanding research were also established at this time. A nation-wide prize essay contest among high school and college students was made possible by the gift of Mr. and Mrs. Francis P. Garvan, administered by the American Chemical Society,‡ in which \$6,000 was awarded in six prizes of \$20 each in every state of the Union for the best essays displaying an understanding of the importance of chemistry in our national life.<sup>27</sup> In 1928 Edward G. Acheson entrusted \$25,000 to the American Electrochemical Society to be the source of a biennial award of a gold medal and \$1,000 cash for distinguished work in electrochemistry,<sup>28</sup> and the following year the American Association for the Advancement of Science made a similar money award, without a medal, for the "most noteworthy contribution to science presented at the annual meeting." This was awarded

\* For officers, 1923-29, see Appendix XLIX.

† Appointed by M. L. Crossley, pres., this committee consisted of Prof. Jas. Kendall, Columbia, chmn.; Prof. Treat B. Johnson, Yale; H. C. Parmelee, ed., *Chem. Met. Eng.*; W. H. Walker, consulting chem.; Edgar F. Smith, provost, Penn. U.; Dr. R. H. Bogue, Lafayette Coll.; Dr. Maurice L. Dolt, Calco Chemical Co., secy.

‡ The original committee administering the contests comprised Harrison E. Howe, chmn.; Wilder D. Bancroft, Chas. H. Herty, and Alexander Williams, Jr., of the Chemical Foundation, secy.

the first year to Dr. Oliver Kamm,\* for his isolation of the hormones from the posterior lobe of the pituitary gland.<sup>29</sup> The will of Elizabeth Blu Frasch, widow of Herman Frasch, who died in 1924, left the residue of her estate after personal gifts and legacies to a fund to be administered with the advice of the American Chemical Society, for the encouragement of research in agricultural chemistry. This fund, which was unsuccessfully contested by the heirs, amounted in the end to some \$900,000.<sup>30</sup>

Two new chemical societies appeared during the 1920's. In 1923 the American Institute of Chemists was organized by a group in New York desirous of establishing a national professional organization of chemists with prerequisites of membership demanding technical training and practical experience. The first president was Dr. Horace Greeley Byers; † Lloyd Van Doren, patent attorney, was vice-president; Clark K. Simon, president of the Dye Products & Chemical Company, treasurer. The secretary was Lloyd Lamborn, editor of *Chemical Age* (N. Y.), whose agitation for a strictly professional society of chemists had been largely responsible for the birth of the new organization.<sup>31</sup> From the beginning the American Institute of Chemists gave evidence of purposeful virility. It had not only the prominent and energetic committee on professional training mentioned above, but in March 1927 it held a conference meeting in the newly opened Sterling Chemistry Laboratory at Yale at which the knotty problem of chemists' contracts of employment was thoroughly thrashed out.<sup>32</sup> Constructive papers from different points of view by William M. Grosvenor, L. V. Redman (read by C. R. Downs), and Arthur L. Corbin of the Yale Law School, introduced a comprehensive, constructive discussion. ‡ In 1927 another professional group organized the Association of Consulting Chemists & Chemical Engineers to establish and maintain high ethical standards of consulting practice. The first officers were Hal T. Beans § of Columbia, president; Irving Hochstadter, vice-pres.; C. V. Ekroth, secretary; and Jerome Alexander, treasurer. The directors were A. G. Stillwell, John M. Weiss, A. M. Smoot, Robert Schwarz, A. W. S. Thomas, F. C. Gephart, and Charles V. Bacon.<sup>33</sup>

\* Dir. research of Parke, Davis & Co., and since 1928 scientific dir., Kamm was born in Ill., 1888, and trained at U. Ill. (B.S., 1911; M.S., 1913; Ph.D., 1915).

† Byers was at the time head of the Chem. Dept., Cooper Union, having previously taught at Tarkio Coll. and Washington U. (Seattle) and subsequently going to Bur. Chem. & Soils as chief of the Div. Soil Chem. & Phys. He was born in Pulaski, Pa., 1872, and retired in 1942. For other officers, 1923-29, see Appendix XLIX.

‡ The speakers were E. J. Barry, Williams Haynes, Chas. H. Herty, Howard C. Parmelee, and John M. Weiss.

§ Prof. Beans served as pres. until 1930 and has been dir. since 1929. A Kansan, born in 1876, he studied at U. Nebr. (B.S., 1899; A.M., 1900) and Columbia (Ph.D., 1904), where he has been teaching since 1902, becoming full prof. in 1921.

In the drug branch of the industry, the American Pharmaceutical Association continued to be official headquarters for scientific research. The original papers and the annual reports on research activities published in its *Journal* covered these activities admirably, and the Association directly stimulated scientific investigations by its Ebert prize and by frequent grants from its research funds.<sup>34</sup> But the American Pharmaceutical Manufacturers' Association was becoming more and more active along these lines, and at its 1928 meeting took long steps in this direction.<sup>35</sup> It created a Research Board consisting of the chief chemists of all member firms for the interchange of scientific and technical information. It established a permanent resident representative in Washington. It further proposed a conference of industry leaders with the Federal Trade Commission to find and eliminate unfair trade practices and also a census of physicians to determine their prescribing habits.

The Chemical Exposition continued to grow in stature and influence, especially after 1923, when it came through what threatened to be a critical schism. Capitalizing the criticism that the Exposition was becoming more and more an equipment display, Adriaan Nagelvoort, formerly one of its comanagers, proposed a strictly chemical show. Recognizing that such a division of support would be costly and less effective in accomplishing the educational purposes, the Salesmen's Association offered itself as arbiter and appointed a committee\* to investigate and report recommendations. Acting favorably on this report, the Chemical Exposition management agreed to a biennial show and pledged to set aside five per cent of the gross receipts, estimated to be about \$3,000, to be spent by the Exposition Advisory Committee on some educational or other public-purposed project in connection with the Exposition. At the same time the Advisory Committee, which previously had been composed almost exclusively of chemists and chemical engineers, was enlarged to include representatives of chemical and apparatus manufacturers.<sup>36</sup> The new members were Dr. Charles L. Reese of du Pont, at the time president of the Manufacturing Chemists' Association; John W. Boyer, sales manager of Mathieson Alkali, then president of Salesmen's Association; Percy D. Schenck, president of Duriron; William Moore of New Jersey Zinc; Milton Kutz of Roessler & Hasslacher; Adolph G. Rosengarten of Powers-Weightman-Rosengarten; Thomas C. Oliver of Oliver Filters; R. Gordon Walker of Chemical Construction Company; Harry J. Schnell, manager of the *Oil, Paint & Drug Reporter*; and Williams Haynes, publisher of *Drug & Chemical Markets*.<sup>37</sup> Nagelvoort withdrew, and the benefits of these

\* Williams Haynes, chmn.; John W. Boyer, George M. Dunning, Walter Goff, A. C. Kalbfleisch, and Jos. Wrench. For full text of the committee's report, see *Drug Chem. Mkts.* 12, 204 (1923).

changes were reaped by the Exposition in an increasing number of chemical exhibitors and by the industry at the Tenth Exposition, 1925, when courses of a week's intensive training in practical technique were initiated<sup>38</sup> for college students under the direction of Dr. William T. Read.\* At the same time the Association of Chemical Equipment Manufacturers, feeling that it would be advantageous to display their wares more frequently and in different sections of the country, organized a cooperative exhibition which was held at Providence in 1925 and at Cleveland in 1926.<sup>39</sup>

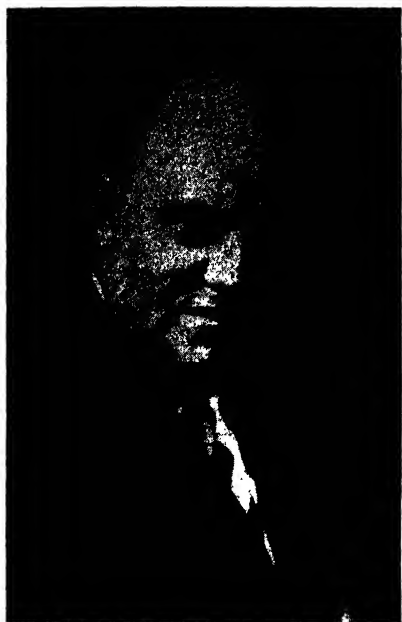
Government activities began to touch the industry more and more closely. The Department of Commerce was solicitous to cooperate with the industry† and Herbert Hoover's recognition of the place of chemicals in the national economy did much to emphasize the prominence which the industry achieved during World War I. At the first break of the depression in the autumn of 1929 President Hoover called to Washington industry leaders who appointed 72 men to organize the nucleus of an Economic Council.<sup>40</sup> E. M. Allen, president of Mathieson Alkali, represented the chemical industry. The Commerce Department was itself broadened during this period when the Bureau of Mines and the Patent Office were transferred to it from the Department of the Interior.<sup>41</sup> Simplification and standardization, favorite projects of Hoover's, were furthered by the Bureau of Standards which in 1927 issued the first *Standards Yearbook* and in 1928 the *National Directory of Commodity Specifications*, containing some 27,000 specifications covering 5,000 commodities.<sup>42</sup>

In the Department of Agriculture, a major event touching the chemical industry was the consolidation in 1927 of the Bureau of Chemistry, the Bureau of Soils, and the Fixed Nitrogen Research Laboratory into the new Bureau of Chemistry and Soils. Dr. Henry G. Knight, dean of the Agricultural College, University of West Virginia, was appointed the chief, succeeding Dr. Charles Albert Browne, who had been in charge since 1923 and who became chief chemist and supervisor of chemical research.<sup>43</sup>

The Chemical Warfare Service made some interesting commercial contributions during the 1920's. Having been established as a permanent part of the Army in 1920, its military importance was broadened in

\* Read's enthusiasm and devotion were chiefly responsible for the success of these student courses. A Texan by birth, he was graduated from Austin Coll., A.B., 1905, A.M., 1908, with an A.M., Texas U., 1915, and a Ph.D., Yale, 1921. He taught at Texas U., Harvard, and Yale, was prof. chem., Texas Technol. Coll., and in 1930 became dean of chem. at Rutgers. He has been chmn. of the N. J. Sect., Am. Chem. Soc., and vice-pres., Am. Inst. Chem. He is author of the widely used text, *Industrial Chemistry* (3d ed., 1943).

† See Chap. 1.



**SIDNEY D. KIRKPATRICK**



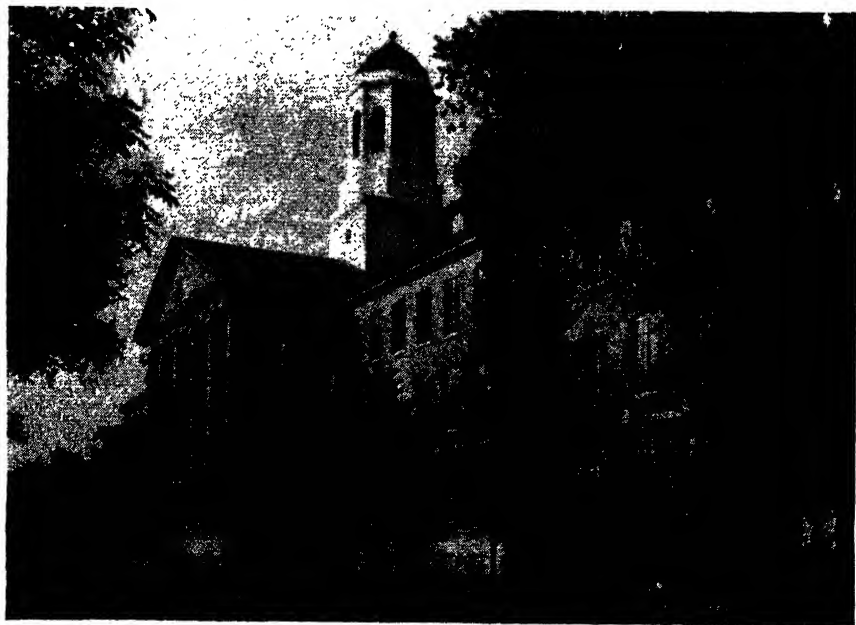
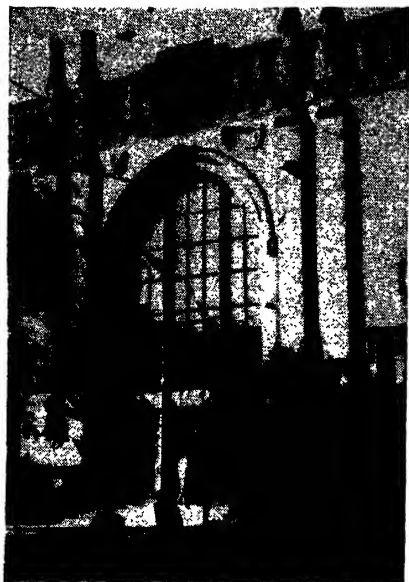
**GERALD L. WENDT**



*Chemical & Metallurgical Engineering*  
**CHARLES A. BROWNE**



*Chemical & Metallurgical Engineering*  
**HENRY G. KNIGHT**



Sterling Chemistry Laboratory, Yale University (*left*); Chandler Laboratories, Columbia University (*right*); Edward Mallinckrodt Chemical Laboratories, Harvard University (*bottom*).

1922 by the establishment of a naval unit at the Edgewood Arsenal, and its status was raised in 1925 when the commandant, Amos A. Fries, was promoted to Major General.<sup>44</sup> During the period peacetime applications were studied. A nontoxic tear gas for controlling mobs was perfected and distributed to the police. Important work was done in arsenical insecticides, antifouling paint for ship bottoms and piers, and in protective measures against industrial poisons.<sup>45</sup> In 1929 Major General Fries was succeeded by Col. Harry L. Gilchrist, previously chief medical officer of the Chemical Warfare Service, under whose direction these toxicity studies were continued and expanded.<sup>46</sup>

The transition from wartime to peacetime conditions also brought changes among the chemical publications. *Chemical & Metallurgical Engineering*, which during the war, when news was in great demand, had become a weekly, returned to monthly publication in 1925, and in 1928 Howard C. Parmelee was succeeded as editor by Sidney D. Kirkpatrick.\* Also in 1925 the *Chemical, Color & Oil Record*, which had changed from a daily to a weekly in 1923 with Wylie F. Tuttle as business manager and William E. Tufts as editor, combined with the *Chemical Age* (N. Y.), Lloyd Lamborn, editor, and adopted its name.<sup>47</sup> Two years later, recognizing the increasing importance and separation of the two great branches of chemical industry, the weekly, *Drug & Chemical Markets* became two monthly publications, *Chemical Markets* and *Drug Markets*. At this time *Chemical Markets* made the interesting innovation in publishing practice, which has since been widely adopted by technical and trade papers in many fields, of naming an advisory board of consulting editors: Robert T. Baldwin, Benjamin T. Brooks, Charles R. Downs, William M. Grosvenor, Arthur D. Little, Charles H. MacDowell, John E. Teeple, Theodore B. Wagner, Milton C. Whitaker, and Frank C. Whitmore.

At the very close of the Booming Twenties, Maurice Holland, discussing research<sup>48</sup> wrote, "Industrially it seems to me we are approaching the end of the era of mechanical efficiency. Automatic machinery has been developed; power application expanded; standardization inaugurated; management, engineering, and efficiency systems installed; and, in short, all the devices of science, applied and engineering, have been employed in the evolution of modern industry." Even this trained

\* One of the best known, best liked "public citizens" of the chemical world, Kirkpatrick has by word and deed furnished constructive leadership since the time he, then a Lt. in Chem. Warfare Serv., was a chem. advisor to the Paris Peace Conference. He was born in Urbana, Ill., 1894, and got his A.B., 1916, at Ill. U. He has been pres., Am. Inst. Chem. Engrs. and Am. Electrochem. Soc.; chmn. of the Am. Sect., Soc. Chem. Ind., and counselor, Am. Chem. Soc. He has been awarded the Silver Anniversary medal of the Am. Inst. Chem. Engrs., the Chem. Ind. medal, and an hon. D.Sc. from Clarkson Coll. Tech. in 1946.



observer on the sidelines of our industrial activity failed to carry his shrewd observation to its ultimate conclusion. It is small wonder then that those in the maelstrom of chemical development and those further removed from the chemical field alike did not recognize the economic revolution implicit in the adoption of chemical raw materials and chemical processing methods to scores of essentially mechanical industries. In retrospect we realize that this trend assumed definite direction and gained great momentum during the 1920's, and with this knowledge we can comprehend the distinctive, almost unique development of the American chemical industry during the Great Depression that followed.

## REFERENCES

1. A. H. Swift, *Ind. Eng. Chem.* 20, 657 (1928); W. J. Hale, *J. Chem. Educ.* 10, 464 (1933).
2. *Chem. Mkts.* 28, 359 (1931).
3. *J. Am. Pharm. Assoc.* 17, 313 (1928).
4. *O.P.D. Repr.* 42 (Oct. 27, 1919); 28 (Nov. 3, 1919).
5. *Drug Chem. Mkts.* 12, 1245 (1923).
6. *Chem. Mkts.* 19, 345, 357, 605, 689 (1926); *Ind. Eng. Chem., News Ed.* 3 (Sept. 10, 1926).
7. *Chem. Mkts.* 20, 784, 951, 981 (1927); 21, 43, 106, 127, 146 (1927).
8. *Ibid.* 21, 335 (1927).
9. *Ibid.* 23, 159 (1928); abstracts of papers, *ibid.* 245; original papers, *Ind. Eng. Chem.* 20, 1128-47 (1928).
10. *O.P.D. Repr.* 79 (June 25, 1923); *Ind. Eng. Chem.* 15, 754 (1923); *Chem. Met. Eng.* 28, 1117 (1923).
11. *Pharm. Era.* 58, 62 (1924).
12. Apr. 30-July 30, 1923, p. 21.
13. *Chem. Mkts.* 21, 108 (1927).
14. *J. Am. Pharm. Assoc.* 14, 1059 (1925).
15. *Ind. Eng. Chem., News Ed.* 5 (Apr. 10, 1923).
16. *Drug Chem. Mkts.* 18, 673 (1925).
17. *J. Am. Pharm. Assoc.* 16, 597 (1927).
18. *Drug Chem. Mkts.* 17, 227 (1925).
19. *Ibid.*
20. *Ind. Eng. Chem.* 15, 315, 462 (1923); *Drug. Circ.* 66, 198 (1923).
21. *J. Am. Pharm. Assoc.* 12, 741 (1923); *Ind. Eng. Chem.* 15, 979 (1923).
22. *Ind. Eng. Chem.* 18, 2 (1926); *Chem. Mkts.* 21, 788 (1927).
23. *J. Am. Pharm. Assoc.* 17, 313 (1928).
24. *Drug Chem. Mkts.* 17, 78 (1925).
25. *J. Am. Pharm. Assoc.* 10, 116 (1921).
26. *Drug Chem. Mkts.* 16, 583 (1925).
27. *Ibid.* 13, 677 (1923); *Chem. Met. Eng.* 29, 552 (1923); *Ind. Eng. Chem., News Ed.* 6 (Sept. 20, 1923).
28. *Chem. Met. Eng.* 35, 646 (1928).
29. *Drug. Circ.* 73, 85 (1929).
30. D. H. Killeffer, *Ind. Eng. Chem.* 17, 995 (1925).
31. *O.P.D. Repr.* 22 (Jan. 29, 1923); *Drug Chem. Mkts.* 12, 268 (1923); *Chem. Met. Eng.* 28, 326 (1923), 29, 643 (1923); *Ind. Eng. Chem., News Ed.* 3 (Feb. 10, 1923).
32. *Chem. Mkts.* 20, 483 (1927).
33. *Ibid.* 469.
34. H. V. Arny, *J. Am. Pharm. Assoc.* 12, 623 (1923).
35. *Ibid.* 17, 618 (1928); *Drug. Circ.* 72, 14 (1928).
36. *Ind. Eng. Chem., News Ed.* 7 (Feb. 10, 1923); *Chem. Met. Eng.* 28, 228 (1923).
37. *Drug Chem. Mkts.* 12, 720 (1923).
38. *Ibid.* 17, 826, 915, 983 (1925); *J. Am. Pharm. Assoc.* 14, 727 (1925).
39. *Drug Chem. Mkts.* 17, 418 (1925); 18, 1207 (1926).
40. *Chem. Mkts.* 36, 69 (1930).
41. Killeffer, *op. cit.*
42. *Ind. Eng. Chem.* 20, 42 (1928); *O.P.D. Repr.* 18 (Apr. 13, 1931).
43. *Chem. Met. Eng.* 33, 774 (1926); 34, 584 (1927).
44. Killeffer, *op. cit.*; E. W. Brown, *Chem. Met. Eng.* 34, 619 (1927).
45. A. A. Fries, *Ind. Eng. Chem.* 20, 1079 (1928).
46. *Chem. Mkts.* 24, 403 (1929).
47. *Drug Chem. Mkts.* 16, 569 (1925).
48. In Wile, *Century of Industrial Progress.*

## Appendix I

### TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS, 1930

Abrasives, artif., crude..	Free	muriatic, & anhydride.	Free
ground .....	1¢ lb.	nitric, & anhydride ...	Free
Acenaphthene .....	Free	oleic (red oil) .....	20%
Acetaldehyde & acetaldol	6¢ lb. & 30%	oxalic .....	6¢ lb. <sup>c</sup>
Acetanilide, med. ....	7¢ lb. & 45% <sup>a</sup>	phenylglycine- <i>o</i> -	
nonmed. ....	7¢ lb. & 40% <sup>a</sup>	carboxylic .....	7¢ lb. & 40% <sup>a</sup>
Acetone & acetone oil ..	20%	phosphoric .....	2¢ lb.
Acetphenetidine .....	7¢ lb. & 45% <sup>a</sup>	phthalic .....	7¢ lb. & 40% <sup>a</sup>
Acid, acetic, under 65%	1½¢ lb.	anhydride .....	7¢ lb. & 40% <sup>a</sup>
over 65% .....	2¢ lb.	picric .....	7¢ lb. & 45% <sup>a</sup>
anhydride .....	3½¢ lb.	pyrogallie .....	12¢ lb.
acetylsalicylic .....	7¢ lb. & 45% <sup>a</sup>	salicylic, & salts, med..	7¢ lb. & 45% <sup>a</sup>
aminobenzoic .....	7¢ lb. & 40% <sup>a</sup>	nonmed. ....	7¢ lb. & 40% <sup>a</sup>
aminosalicylic .....	7¢ lb. & 40% <sup>a</sup>	stearic .....	25% <sup>b</sup>
arsanilic .....	7¢ lb. & 40% <sup>a</sup>	sulfanilic .....	7¢ lb. & 40% <sup>a</sup>
arsenic .....	3¢ lb.	sulfuric, & anhydride..	Free
arsenious .....	Free	tannic, to 50% .....	5¢ lb.
benzoic, med. ....	7¢ lb. & 45% <sup>a</sup>	50% & over, med. ..	18¢ lb.
nonmed. ....	7¢ lb. & 40% <sup>a</sup>	nonmed. ....	11¢ lb.
boric .....	1¢ lb.	tartaric .....	8¢ lb.
chloroacetic .....	5¢ lb.	tetrachlorophthalic ...	7¢ lb. & 40% <sup>a</sup>
chlorophthalic .....	7¢ lb. & 40% <sup>a</sup>	thiosalicylic .....	7¢ lb. & 40% <sup>a</sup>
chromic .....	25% <sup>b</sup>	tungstic .....	60¢ lb. & 40%
cinnamic .....	7¢ lb. & 40% <sup>a</sup>	valeric, & anhydride ..	Free
citric .....	17¢ lb.	Acids, n.s.p.f., incl. an-	
anresylic .....	3½¢ lb. & 20% <sup>a, c</sup>	hydrides .....	25% <sup>b</sup>
dichlorophthalic ....	7¢ lb. & 40% <sup>a</sup>	Adonite .....	50%
diethylbarbituric, salts		Alcohol, amyl .....	6¢ lb.
& comp. ....	\$2.50 lb.	butyl .....	6¢ lb.
formic .....	3¢ lb.	ethyl, mixt. & comp.	
gallic .....	6¢ lb.	up to 20% .....	20¢ lb. & 25%
glycerophosphoric, salts		20-50% .....	40¢ lb. & 25%
& comp. ....	35%	over 50% .....	80¢ lb. & 25%
hydrochloric & hydro-		nonbeverage .....	15¢ gal.
fluoric, & anhy-		hexyl .....	6¢ lb.
drides .....	Free	methyl (wood alc.) ..	18¢ gal. <sup>c</sup>
hydroxyphenylarsinic .	7¢ lb. & 40% <sup>a</sup>	phenylethyl .....	7¢ lb. & 45% <sup>a</sup>
lactic (not less than		propyl .....	6¢ lb.
25% ad valorem,		vinyl .....	6¢ lb. & 30%
anhydrides deter-		Alcohols, unsat. ....	6¢ lb. & 30%
mined as acids)		Aldehyde ammonia &	
to 30% .....	2¢ lb.	aldol .....	6¢ lb. & 30%
30-55% .....	4¢ lb.	Alizarin, nat. & deriv. ..	7¢ lb. & 45% <sup>a</sup>
55% & over .....	9¢ lb.	Alkalies & alkaloids,	
metanilic .....	7¢ lb. & 40% <sup>a</sup>	n.s.p.f. ....	25%
mixed (sulfuric-nitric)	Free		

<sup>a</sup> Based on American selling price of competitive U. S. article, if none, on U. S. value;

<sup>b</sup> Basket clause; <sup>c</sup> Rate established by Presidential proclamation; <sup>d</sup> Free, if chiefly fertilizer;

<sup>e</sup> 1¢ if domestic production not 25% of consumption in 3 yrs. or 30% in 4 yrs. or 50% in 5 yrs.; <sup>f</sup> n.s.p.f. in 1922 Tariff.

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS, 1930 (*Continued*)

Alloys, of Ba, B, Ca, Cb, Sr, Ta, Th, Ti, U, V, Zr (2 or more) . . . . .	25%	Arabinose . . . . .	50%
n.s.p.f., of above (1 or more) with Al, Cr, Co, Cu, Mn, Ni, Si (1 or more) . . . . .	25%	Argols, tartar, & wine lees, crude or part- ly ref., to 90% K bitartrate . . . . .	Free
Alloys, for steel, n.s.p.f..	25%	over 90% . . . . .	5¢ lb.
Aluminum, & alloys, crude . . . . .	4¢ lb.	Arsenic . . . . .	6¢ lb.
foil, less .006 in. . . . .	40%	sulfide, other salts & comp., n.s.p.f., 10% & over of arsenious acid . . . . .	Free
powder . . . . .	12¢ lb.	Arsphenamine, neoars- phenamine, & simi- lar comp. . . . .	7¢ lb. & 45% <sup>a</sup>
salts & comp., n.s.p.f.. (see also Metals)	25%	Aspirin . . . . .	7¢ lb. & 45% <sup>a</sup>
Aluminum hydroxide ..	1½¢ lb.	Azides . . . . .	12½¢ lb.
—silicon . . . . .	5¢ lb.	Barium (see Metals)	
sulfate (alum cake), to 15% Al & Fe over .1% Fe <sub>2</sub> O <sub>3</sub> equiv... .	¾¢ lb.	carbonate, precip. ....	1½¢ lb.
over 15% Al & Fe to .1% Fe <sub>2</sub> O <sub>3</sub> equiv... .	¾¢ lb.	chloride . . . . .	2¢ lb.
Amines, hydroxyalkyl & alkylenedi- . . . . .	6¢ lb. & 30%	dioxide . . . . .	6¢ lb. <sup>c</sup>
Aminoanthraquinone, aminonaphthol, aminophenetole, aminophenol . . . . .	7¢ lb. & 40% <sup>a</sup>	hydroxide . . . . .	1¼¢ lb.
Ammonia, anhyd. liq. ..	2½¢ lb. <sup>d</sup>	nitrate . . . . .	2¢ lb.
Ammonia alum (ammo- nium aluminum sulfate) . . . . .	¾¢	oxide . . . . .	2½¢ lb.
Ammonium bicarbonate	2¢ lb.	sulfate, precip. ....	1¼¢ lb.
carbonate . . . . .	2¢ lb.	Barytes, crude . . . . .	\$4 ton
chloride (sal ammoni- ac) . . . . .	1¼¢ lb.	ground . . . . .	\$7.50 ton
nitrate . . . . .	1¢ lb.	Bauxite, crude . . . . .	\$1 ton
perchlorate . . . . .	1½¢ lb.	ref. . . . .	½¢ lb.
phosphate . . . . .	1½¢ lb.	Benzalchloride . . . . .	7¢ lb. & 40% <sup>a</sup>
sulfate . . . . .	Free	Benzaldehyde, med. ....	7¢ lb. & 45% <sup>a</sup>
Amyl acetate . . . . .	7¢ lb.	nonmed. . . . .	7¢ lb. & 40% <sup>a</sup>
nitrate . . . . .	25%	Benzanthrone . . . . .	7¢ lb. & 40% <sup>a</sup>
Anethole . . . . .	45%	Benzene . . . . .	Free
Anhydrides, n.s.p.f. ....	25%	Benzidine, & sulfate ....	7¢ lb. & 40% <sup>a</sup>
Aniline oil, & salt . . . . .	7¢ lb. & 40% <sup>a</sup>	Benzoquinone . . . . .	7¢ lb. & 40% <sup>a</sup>
Anthracene, to 30% . . . .	Free	Benzoyl chloride . . . . .	7¢ lb. & 40% <sup>a</sup>
30% & over . . . . .	7¢ lb. & 40% <sup>a</sup>	Benzyl acetate & benzoate	7¢ lb. & 45% <sup>a</sup>
Anthracene oil . . . . .	Free	chloride . . . . .	7¢ lb. & 40% <sup>a</sup>
Anthraquinone . . . . .	7¢ lb. & 40% <sup>a</sup>	Benzylethylaniline . . . .	7¢ lb. & 40% <sup>a</sup>
Antimony . . . . .	2¢ lb.	Beryllium . . . . .	25%
liquated . . . . .	¼¢ lb.	Bismuth . . . . .	7½%
salts & comp., n.s.p.f..	1¢ lb. & 25%	comp., salts, mixt. ....	35%
Antimony oxide . . . . .	2¢ lb.	Black pigments (carbon, gas, lampblack), n.s.p.f. . . . .	20%
—potassium tartrate ...	6¢ lb.	Blanc fixe . . . . .	1¼¢ lb.
sulfide . . . . .	1¢ lb. & 25%	Bleaching powder . . . . .	¾¢ lb.
Antipyrine . . . . .	7¢ lb. & 45% <sup>a</sup>	Blue pigments, & all with iron ferri- or ferro- cyanide . . . . .	8¢ lb.
		Bone black, chars & car- bon . . . . .	20%
		Borax & borates, crude, n.s.p.f. . . . .	Free
		ref. . . . .	¼¢ lb.

Boron ( <i>see</i> Metals)		Chemical elements, mixt.,	
carbide .....	25%	to 20% alc. ....	20¢ lb. & 25%
Bromine .....	10¢ lb.	20-50% .....	40¢ lb. & 25%
comp., n.s.p.f. ....	10¢ lb.	over 50% .....	80¢ lb. & 25%
Bromobenzene .....	7¢ lb. & 40% <sup>a</sup>	n.s.p.f. ....	25%
Butyl acetate .....	7¢ lb.	Chemicals, drugs, etc.,	
Butylene chlorohydrin,		capsules, pills, tab-	
dichloride, glycol. ....	6¢ lb. & 30%	lets, etc. (med.	
Butyraldehyde .....	6¢ lb. & 30%	doses) .....	25% min.
Cadmium .....	15¢ lb.	Chemicals, photographic	
Caffeine .....	\$1.25 lb.	synth. odoriferous or	
citrate .....	75¢ lb.	aromatic, mixed,	
comp. ....	25%	n.s.p.f. ....	40¢ lb. & 50%
Calcium ( <i>see</i> Metals)		unmixed, n.s.p.f. ....	45%
acetate .....	1¢ lb.	Chestnut ext. ....	15%
arsenate .....	Free	China clay (kaolin) ...	\$2.50 ton
borate, crude .....	Free	Chloral hydrate .....	35%
carbide .....	1¢ lb.	Chlorinated lime .....	¾¢ lb.
chloride, crude .....	Free	Chlorobenzene .....	7¢ lb. & 40% <sup>a</sup>
cyanamide .....	Free	Chloroform .....	4¢ lb.
molybdate .....	50¢ lb. & 15%	Chrome, chromium ....	30%
nitrate .....	Free	( <i>see also</i> Ferrochrome;	
oxalate .....	7¢ lb.	Metals)	
sulfate, precip. ....	½¢ lb.	Chromeyellow, green, etc.	25%
tartrate, crude .....	Free	Chromium comp. (car-	
Calomel, & Hg prep. ...	22¢ lb. & 25%	bide, nickel, <sup>†</sup> sili-	
Camphor, crude, nat. ...	1¢ lb.	con, <sup>†</sup> sulfate, vana-	
ref., synth. ....	5¢ lb.*	dium <sup>†</sup> ) .....	25%
Carbazole, to 65% ....	Free	Citral .....	45%
65% & over .....	7¢ lb. & 40% <sup>a</sup>	Clays or earths, activated	
Carbon dioxide, up to 1		China or kaolin .....	¼¢ lb. & 30%
lb. with carton ...	1¢ lb.	crude, n.s.p.f. ....	\$2.50 ton
Carbon tetrachloride ...	1¢ lb.	mfd., n.s.p.f. ....	\$1 ton
Carbons, decolorizing &		.....	\$2 ton
activated .....	45%	Cleaning & polishing	
Casein .....	5½¢ lb.	prep., n.s.p.f. (non-	
comp., unmf. ....	25¢ lb.	alc.) .....	25%
Cellulose acetate & comp.,		Coal tar, crude .....	Free
unmf. ....	50¢ lb.	acids, n.s.p.f. ....	3½¢ lb. & 20% <sup>a</sup>
mfd. ....	80%	distillates, to 5% tar	
Cellulose esters & ethers		acids below 190°	
comp. ....	40¢ lb.	C., nonmed. colors,	
mfd., partly mfd. ....	60%	dyes .....	Free
vulcanized .....	30%	5% & over tar acids.	7¢ lb. & 40% <sup>a</sup>
sol. ....	30¢ lb.	intermediates, n.s.p.f. ...	7¢ lb. & 40% <sup>a</sup>
Cerium .....	\$2 lb.	Coal-tar chemicals: col-	
alloys .....	\$2 lb. & 25%	ors, dyes, stains, &	
Cerium fluoride, nitrate,		med., n.s.p.f. ....	7¢ lb. & 45% <sup>a</sup>
& salts, n.s.p.f. ...	35%	color acids, bases, lakes;	
Cesium .....	25%	leuco comp., in-	
Chalk (whiting, Paris		doxyl comp. ....	7¢ lb. & 45% <sup>a</sup>
white), dry .....	¾¢ lb.	Cobalt .....	Free
ground in oil .....	¾¢ lb.	linoleate .....	10¢ lb.
precip. ....	25%	oxide .....	20¢ lb.
( <i>see also</i> French chalk)		salts & comp., n.s.p.f. ...	30%
Charcoal, nonpigment ..	Free	sulfate .....	10¢ lb.
		( <i>see also</i> Metals)	

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS, 1930 (*Continued*)

Cocaine, salts, esters, deriv. ....	\$2.60 oz.	Dulcite .....	50%
Collodion, & other pyroxylin sol. ....	30¢ lb.	Dyeing & tanning ext., nonalc., n.s.p.f. ...	15%
mfd., partly mfd. articles .....	80%	Dyeing & tanning materials, nonalc., vegetable, n.s.p.f. ....	Free
unmfd. articles .....	50¢ lb.	Dynamite .....	1¼¢ lb.
Columbium, ductile, & alloys .....	40%	Earths (ochers, siennas, umbers), crude ...	½¢ lb.
(see also Metals)		ground .....	⅓¢ lb.
Copperas (ferrous sulfate) .....	Free	Ecgonine, salts, esters, deriv. ....	\$2.60 oz.
Corrosive sublimate ....	22¢ lb. & 25%	Emery, ground .....	1¢ lb.
Corundum .....	1¢ lb.	Epsom salt (magnesium sulfate) .....	¾¢ lb.
Coumarin, nat. ....	7¢ lb. & 45% <sup>a</sup>	Ergot .....	Free
synth. ....	7¢ lb. & 45% <sup>a</sup>	Esters & ethers, n.s.p.f., to 10% alc. ....	25%
Cream of tartar .....	5¢ lb.	over 50% alc. ....	80¢ lb. & 25%
Creosote oil (dead oil) ..	Free	Ethyl acetate .....	3¢ lb.
Cresol (o-, m-, p-), 90% or over .....	3½¢ lb. & 20% <sup>a</sup>	chloride .....	15¢ lb.
Crotonaldehyde .....	6¢ lb. & 30%	dibromide .....	10¢ lb.
Cryolite .....	Free	ether (sulfuric ether) ..	4¢ lb.
Cumene .....	Free	Ethylene chlorohydrin, dichloride, glycol, oxide .....	6¢ lb. & 30%
Cumidine .....	7¢ lb. & 40% <sup>a</sup>	Ethylhydrocupreine, salts & comp. ....	20¢ oz.
Cupric acetate & subacetate (verdigris) ...	Free	Eucalyptol .....	25%
iodide, crude .....	Free	Explosives (coal-tar, excl. smokeless) .....	7¢ lb. & 45% <sup>a</sup>
oxide .....	25%	Extracts, flavoring, nonalc., n.s.p.f. ....	25%
sulfate (blue vitriol) ..	Free	tanning & dyeing, nonalc., n.s.p.f. ....	15%
Cuprous oxide .....	35%	Feldspar, crude .....	\$1 ton; 50¢ ton <sup>c</sup>
Cyanides, & mixt., comp. n.s.p.f. ....	Free	Ferric chloride .....	25%
Cymene .....	Free	Ferroalloys (B, P, Si, Ti, U, V, Zr) .....	25%
Dehydrothiotoluidine ...	7¢ lb. & 40% <sup>a</sup>	Ferroaluminum-silicon ..	5¢ lb.
Dextrin (potato, flour) ..	3¢ lb.	-vanadium .....	25%
n.s.p.f. ....	2¢ lb.	Ferroboron, -cerium ....	25%
Dextrose, to 99.7% ....	2¢ lb.	Ferrochrome, -chromium, to 3% C .....	30%
over 99.7% .....	50%	over 3% C .....	2½¢ lb.
Diamines, alkylene ....	6¢ lb. & 30%	Ferromanganese .....	1½¢ lb.
Diaminostilbene .....	7¢ lb. & 40% <sup>a</sup>	-vanadium .....	25%
Dianisidine .....	7¢ lb. & 40% <sup>a</sup>	Ferromolybdenum .....	50¢ lb. & 15%
Diethyl sulfate .....	25%	Ferrophosphorus .....	25%
Dihydroxynaphthalene ..	7¢ lb. & 40% <sup>a</sup>	Ferrosilicon .....	25%
Dimethyl-aminophenol, -aniline, -phenylbenzyl ammonium hydroxide, -phenylenediamine ....	7¢ lb. & 40% <sup>a</sup>	8-60% Si .....	2¢ lb.
Dimethyl sulfate .....	25%	60-80% .....	3¢ lb.
Dinitrobenzene, -chlorobenzene, -naphthalene, -phenol, -toluene .....	7¢ lb. & 40% <sup>a</sup>	80-90% .....	4¢ lb.
Diphenylamine .....	7¢ lb. & 40% <sup>a</sup>	over 90% .....	8¢ lb.
Diphenyloxide .....	7¢ lb. & 45% <sup>a</sup>	-aluminium .....	5¢ lb.

-aluminum-vanadium . . . . .	25%	Ionone . . . . .	45%
-vanadium . . . . .	25%	Iridium, & comb. . . . .	Free
Ferrotitanium . . . . .	25%	Iron-ammonium & -sodi- um oxalates . . . . .	25%
Ferrotungsten . . . . .	60¢ lb. & 25%	Iron oxide & hydroxide pigments, n.s.p.f. . . . .	20%
Ferrouanium, -vanadi- um, -zirconium . . . . .	25%	sulfide . . . . .	25%
Ferroussulfate (copperas) Flavoring ext., alc. ( <i>see</i> Alcohol, ethyl)	Free	( <i>see also</i> Ferro, Fer- rous)	
nonalc. . . . .	25%	Kaolin . . . . .	\$2.50 ton
Flavors, coal-tar . . . . .	7¢ lb. & 45% <sup>a</sup>	Laudanum . . . . .	60%
Fluorene . . . . .	Free	Lead, alloys, n.s.p.f. . . . .	2½¢ lb.
Fluorspar, over 93% CaF <sub>2</sub> over 97% CaF <sub>2</sub> . . . . .	— \$5.60 ton	comp. & pigments, n.s.p.f. . . . .	30%
under 93% CaF <sub>2</sub> . . . . .	—	Lead acetate, brown, gray, yellow . . . . .	2¢ lb.
under 97% CaF <sub>2</sub> . . . . .	\$8.40 ton	white . . . . .	2½¢ lb.
Formaldehyde (formalin) solid (paraformalde- hyde) . . . . .	1¼¢ lb. 8¢ lb.	( <i>see also</i> Pigments)	
French chalk, crude . . . . .	¼¢ lb.	arsenate . . . . .	3¢ lb.
ground . . . . .	35%	nitrate . . . . .	3¢ lb.
Fuller's earth, crude . . . . .	\$1.50 ton	resinate . . . . .	3¢ lb.
ground . . . . .	\$3.25 ton	Levulose . . . . .	50%
Fulminates . . . . .	12½¢ lb.	Lime, chlorinated (bleach) . . . . .	¾¢ lb.
Fusel oil & mixt. . . . .	6¢ lb.	hydrated, gross wt. . . . .	12¢ cwt.
Galactose . . . . .	50%	n.s.p.f. . . . .	10¢ cwt.
Galalith, unmf'd. . . . .	25¢ lb.	Lime borate . . . . .	Free
mfd. or partly mfd. . . . .	40¢ lb. & 50%	citrate . . . . .	7¢ lb.
Geraniol . . . . .	45%	nitrogen (calcium cy- anamide) . . . . .	Free
Glycerin, crude . . . . .	1¢ lb.	Litharge . . . . .	2½¢ lb.
ref. . . . .	2¢ lb.	Lithium . . . . .	25%
Glycol monoacetate . . . . .	6¢ lb. & 30%	Lithopone, under 30% ZnS . . . . .	1¼¢ lb.
Glycols . . . . .	6¢ lb. & 30%	30% ZnS & over . . . . .	1¼¢ lb. & 15%
Gold, chem. comp. . . . .	25%	Logwood . . . . .	15%
Graphite, amorphous . . . . .	10%	London purple . . . . .	Free
cryst., flake . . . . .	1.65¢ lb.	Lupulin . . . . .	\$1.50 lb.
lump . . . . .	20%	Magnesite, caustic, calc.. crude . . . . .	15½¢ lb.† 15½¢ lb.†
Guaiacol, nat. & deriv. . . . .	7¢ lb. & 45% <sup>a</sup>	dead burned, grained. . . . .	23½¢ lb.
synth. & deriv. . . . .	7¢ lb. & 45% <sup>a</sup>	Magnesium, & scrap . . . . .	40¢ lb.
carbonate . . . . .	7¢ lb. & 45% <sup>a</sup>	alloys of mfs., n.s.p.f. . . . .	40¢ lb. & 20%
Gums & resins, synth. ( <i>see also</i> Resins) . . . . .	4¢ lb. & 30%	carbonate, precip. . . . .	1½¢ lb.
Gunpowder & explosives, n.s.p.f. . . . .	Free	chloride, anhyd. . . . .	1¢ lb.
Gypsum, crude . . . . .	Free	n.s.p.f. . . . .	¾¢ lb.
ground, calc. . . . .	\$1.40 ton	oxide (calc. magnesia) silicofluoride . . . . .	7¢ lb. 25%
Heliotropin . . . . .	45%	sulfate (Epsom salt) . . . . .	¾¢ lb.
Hexamethylenetetramine . . . . .	11¢ lb.	Manganese . . . . .	1⅞¢ lb. & 15%
Hydrogen peroxide . . . . .	25%	-copper . . . . .	25%
Hydroxyalkylamines . . . . .	6¢ lb. & 30%	ore, over 30% Mn . . . . .	1¢ lb.
Indigo, nat. . . . .	7¢ lb. & 45% <sup>a</sup>	over 10% Mn . . . . .	1¢ lb.
synth. . . . .	3¢ lb. & 20% <sup>a</sup>	( <i>see also</i> Ferroman- gane)	
Ink powders, coal-tar . . . . .	7¢ lb. & 45% <sup>a</sup>		
n.s.p.f. . . . .	10%		
Inosite & inulin . . . . .	50%		
Iodine, crude . . . . .	Free		
resublimed . . . . .	10¢ lb.		

TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS, 1930 (*Continued*)

Manganese salts & comp. (borate, linoleate, resinate, sulfate) ..	25%	Ochers, crude .....	¼ ¢ lb.
(see also Metals)		ground .....	¾ ¢ lb.
Mannite & mannose ....	50%	Opium, alkaloids, salts, esters, deriv. ....	\$3 oz.
Melezitose & melibiose ..	50%	crude, to 8.5% anhyd.	
Menthol .....	50¢ lb.	morphine .....	\$6 oz.
Mercury .....	25¢ lb.	8.5% anhyd. morphine & over .....	\$3 lb.
prep. (mercuric oxide)	22¢ lb. & 25%	tinct. & other liq. prep., n.s.p.f. ....	60%
Metals, alloys of Ba, B, Ca, Cb, Sr, Ta, Ti, U, V, Zr (2 or more) .....	25%	Orange mineral .....	3¢ lb.
alloys, n.s.p.f., of above (1 or more) with Al, Cr, Co, Cu, Mn, Ni, Si (1 or more) .....	25%	Osmium, & comb. ....	Free
Methyl anthranilate ....	7¢ lb. & 45% <sup>a</sup>	Palladium, & comb. ....	Free
ethyl ketone .....	20%	Paracetaldehyde .....	6¢ lb. & 30%
salicylate, nat. & synth.	7¢ lb. & 45% <sup>a</sup>	Paraformaldehyde .....	8¢ lb.
Methylantracene .....	Free	Paris green .....	Free
Methylantraquinone ..	7¢ lb. & 40% <sup>a</sup>	Paris white (see Chalk)	
Methylnaphthalene ....	Free	Perfumes, with alc. ....	40¢ lb. & 75%
Mineral salts (from min- eral waters) .....	Free	Periclase (MgO), crude. mfd. ....	2¾ ¢ lb. 2¾ ¢ lb.
Molybdenum, ore .....	35¢ lb.	Phenol .....	3½ ¢ lb. & 20% <sup>a, b</sup>
powder (Fe, Ca, comp. & alloys) .....	50¢ lb. & 15%	Phenolic resin .....	7¢ lb. & 45% <sup>a</sup>
Morphine, & sulfate ....	\$3 oz.	Phenolphthalein .....	7¢ lb. & 45% <sup>a</sup>
Musk, nat. ....	20%	Phenylacetaldehyde ....	7¢ lb. & 45% <sup>a</sup>
synth. ....	7¢ lb. & 45% <sup>a</sup>	Phenylenediamine, phen- ylglycine, phenyl- hydrazine, phenyl- naphthylamine ...	7¢ lb. & 40% <sup>a</sup>
Naphthalene, solid. pt. to 79° C. ....	Free	Phosphates, crude & apa- tite .....	Free
solid. pt. 79° C. & over	7¢ lb. & 40% <sup>a</sup>	Phosphorus .....	8¢ lb.
α-Naphthol .....	7¢ lb. & 40% <sup>a</sup>	oxychloride & trichlo- ride .....	6¢ lb.
β-Naphthol, med. ....	7¢ lb. & 45% <sup>a</sup>	Photographic chemicals (coal-tar) .....	7¢ lb. & 45% <sup>a</sup>
nonmed. ....	7¢ lb. & 40% <sup>a</sup>	Phthalimide .....	7¢ lb. & 40% <sup>a</sup>
Naphthylamine .....	7¢ lb. & 40% <sup>a</sup>	Pigments, iron oxide & iron hydroxide ...	20%
Naphthylenediamine ...	7¢ lb. & 40% <sup>a</sup>	lead, n.s.p.f. ....	30%
Neoarsphenamine ....	7¢ lb. & 45% <sup>a</sup>	n.s.p.f. ....	25%
Nickel, & alloys .....	3¢ lb.	(see also Lead; individ- ual colors)	
oxide .....	Free	Platinum, comp. & mixt.. unmfd. ....	25% Free
Niobium, ductile, & alloys (see also Metals)	40%	Plumbago (see Graphite)	
Niter cake .....	Free	Potassium .....	25%
Nitroaniline, -anthraqui- none, -benzalde- hyde, -benzene, -naphthalene, -phe- nol, -phenylenedia- mine, -toluene, & -toluylenediamine .	7¢ lb. & 40% <sup>a</sup>	-aluminum sulfate (pot- ash alum) .....	¾ ¢ lb.
Nitrosodimethylaniline ..	7¢ lb. & 40% <sup>a</sup>	-antimony tartrate ...	6¢ lb.
Novocaine .....	7¢ lb. & 45% <sup>a</sup>	bicarbonate .....	1½ ¢ lb.
		bichromate .....	2¼ ¢ lb.
		bitartrate (see Argols)	
		bromide .....	10¢ lb.
		carbonate .....	¾ ¢ lb.
		chlorate .....	1½ ¢ lb.

chloride .....	Free	Sal ammoniac (ammonium chloride) ....	1 ¼ ¢ lb.
chromate .....	2 ¼ ¢ lb.	Salicin .....	50%
citrate .....	14 ¢ lb.	Salol .....	7 ¢ lb. & 45%*
cyanide .....	Free	Salt ( <i>see</i> Sodium chloride)	
ferricyanide (red prussiate) .....	7 ¢ lb.	Salt cake, crude .....	Free
ferrocyanide (yellow prussiate) .....	4 ¢ lb.	Santonin, & salts .....	Free
hydroxide (caustic potash) .....	1 ¢ lb.	Satin white (calcium sulfate) .....	½ ¢ lb.
iodide .....	25 ¢ lb.	Selenium, & salts .....	Free
nitrate (saltpeter), crude .....	Free	Sheep dip .....	Free
ref. ....	1 ¢ lb.	Siennas, crude ..	¼ ¢ lb.
perchlorate .....	1 ½ ¢ lb.	ground .....	¾ ¢ lb.
permanganate .....	6 ¢ lb. <sup>c</sup>	Silica, crude, n.s.p.f. ....	\$3.50 ton
salts, crude, n.s.p.f. ....	Free	for pigments .....	Free
-sodium tartrate (Rochelle salt) .....	5 ¢ lb.	Silicon .....	8 ¢ lb.
sulfate .....	Free	-aluminum .....	5 ¢ lb.
Procaine .....	7 ¢ lb. & 45%*	( <i>see also</i> Ferrosilicon; Metals)	
Propylene chlorohydrin, dichloride, glycol.	6 ¢ lb. & 30%	Silver .....	Free
Pyridine .....	Free	comp. & mixt. ....	25%
Pyrites, over 3% Zn ....	1 ½ ¢ lb.	German or nickel, unmfd. ....	20%
Pyroxylin, comp., mfd. or partly mfd. ....	80%	Soapstone, crude .....	¼ ¢ lb.
mfd. ....	50 ¢ lb.	ground .....	35%
liq. sol. ....	30 ¢ lb.	Sodium .....	25%
Quicksilver .....	25 ¢ lb.	acetate .....	25%
Quinaldine .....	7 ¢ lb. & 40%*	arsenate .....	1 ¢ lb.
Quinine sulfate, & cinchona alkaloids & salts .....	Free	benzoate .....	7 ¢ lb. & 45%*
Quinoline .....	7 ¢ lb. & 40%*	bicarbonate .....	Free
Radium, & salts, radioactive subs. ....	Free	bichromate .....	1 ¼ ¢ lb.
Raffinose .....	50%	bisulfite, metabisulfite.	¾ ¢ lb.
Red lead .....	2 ¾ ¢ lb.	borate, crude (borax). ref. ....	Free
Resins: phenol, cresol, phthalic anhydride, coumarone, indene, etc. ....	7 ¢ lb. & 45%*	bromide .....	¼ ¢ lb.
Resorcinol, med. ....	7 ¢ lb. & 45%*	carbonate, calc. (soda ash); hydrated (soda); monohydrated (cryst.) ...	10 ¢ lb.
nonmed. ....	7 ¢ lb. & 40%*	chlorate .....	1 ½ ¢ lb.
Rhamnose .....	50%	chloride (bags, sacks, bbl.) .....	11 ¢ cwt.
Rhodinol .....	45%	bulk .....	7 ¢ cwt.
Rhodium, comp. & mixt. nat. ....	25%	chromate .....	1 ¼ ¢ lb.
Ribose .....	Free	citrate .....	12 ¢ lb.
Rochelle salt (potassium-sodium tartrate) ..	5 ¢ lb.	comp., n.s.p.f. ....	25%
Rosin, gum & spirits ....	5%	cyanide .....	Free
Ruthenium, & comb. ...	Free	ferrocyanide .....	2 ¢ lb.
Saccharides, n.s.p.f. ....	50%	fluoride .....	25%
Saccharin .....	7 ¢ lb. & 45%*	formate .....	2 ¢ lb.
Safrole .....	45%	hydrosulfite, & comp. soda) .....	35%
		hydroxide (caustic nitrate .....	½ ¢ lb.
		nitrite .....	Free
		oxalate .....	4 ½ ¢ lb. <sup>c</sup>
			2 ½ ¢ lb.



TARIFF RATES ON CHEMICALS AND THEIR RAW MATERIALS, 1930 (*Continued*)

Sodium phosphate, under 45% water .....	1½¢ lb.
n.s.p.f. ....	¾¢ lb.
-potassium tartrate (Rochelle salt) .....	5¢ lb.
sesquicarbonate .....	¼¢ lb.
silicate .....	¾¢ lb.
silicofluoride .....	1½¢ lb.
sulfate, anhyd. ....	\$3 ton
crude (salt cake, niter cake) .....	Free
cryst. (Glauber's salt) .....	\$1 ton
sulphydrate .....	25%
sulfide, to 35% Na <sub>2</sub> S ..	¾¢ lb.
35% & over .....	¾¢ lb.
sulfite .....	¾¢ lb.
sulfoxylate comp. ....	35%
thiosulfate .....	¾¢ lb.
Sorbite .....	50%
Stearite, crude .....	¼¢ lb.
ground .....	35%
Strontium ( <i>see</i> Metals)	
carbonate (precip.), nitrate, oxide .....	25%
Strychnine, & salts .....	20¢ oz.
Sulfur .....	Free
Sulfur black .....	3¢ lb. & 20% <sup>a</sup>
<i>d</i> -Tagatose & <i>d</i> -talose ...	50%
Talc, crude .....	¼¢ lb.
ground .....	35%
Tanning materials, synth. ( <i>see also</i> Dyeing & tanning) .....	7¢ lb. & 45% <sup>a</sup>
Tantalum, ductile & non-ferrous alloys ...	40%
( <i>see also</i> Metals)	
Tartar ( <i>see</i> Argols)	
Tartar emetic (potassium-antimony tartrate) .....	6¢ lb.
Terpin hydrate .....	35%
Terpineol .....	45%
Tetrachloroethane .....	30%
Tetramethyldiaminobenzophenone & -diphenylmethane. ....	7¢ lb. & 40% <sup>a</sup>
Theobromine .....	75¢ lb.
Thiocarbamilide .....	7¢ lb. & 40% <sup>a</sup>
Thorium, ore .....	Free
nitrate, oxide, & salts, n.s.p.f. ....	35%
( <i>see also</i> Metals)	
Thymol .....	35%
Tin, & bichloride, tetrachloride, & salts ...	25%
Titanium .....	25%
comp., mixt. ....	30%

Titanium-potassium oxalate .....	30%
TNT .....	7¢ lb. & 45% <sup>a</sup>
Tolidine .....	7¢ lb. & 40% <sup>a</sup>
Toluene .....	Free
Toluenesulfochloride & -sulfonamide .....	7¢ lb. & 40% <sup>a</sup>
Toluidine .....	7¢ lb. & 40% <sup>a</sup>
Tolylenediamine .....	7¢ lb. & 40% <sup>a</sup>
Tribromophenol .....	7¢ lb. & 40% <sup>a</sup>
Trichloroethylene .....	30%
Trinitrophenol .....	7¢ lb. & 45% <sup>a</sup>
Trinitrotoluene (TNT) ..	7¢ lb. & 45% <sup>a</sup>
Tungsten .....	60¢ lb. & 50%
alloys, n.s.p.f. ....	60¢ lb. & 25%
carbide powd. ....	60¢ lb. & 50%
comp., n.s.p.f. ....	60¢ lb. & 40%
ore .....	50¢ lb.
Tungstic acid .....	60¢ lb. & 40%
Turmeric .....	Free
Turpentine, gum & spirits .....	5%
Ultramarine blue, under 10¢ lb. value .....	3¢ lb.
over 10¢ lb. value ...	4¢ lb.
Umber, crude .....	½¢ lb.
ground .....	¾¢ lb.
Uranium, oxide & salts ..	Free
( <i>see also</i> Metals)	
Urea .....	Free
Vanadic acid, anhydride, & salts .....	40%
Vanadium, comp. & mixts., n.s.p.f. ....	40%
carbide .....	25%
Vanillin .....	7¢ lb. & 45% <sup>a</sup>
Vermilion reds .....	35¢ lb.
White arsenic .....	Free
White lead .....	2½¢ lb.
Whiting ( <i>see</i> Chalk)	
Wine lees ( <i>see</i> Argols)	
Xylene .....	Free
Xylidine .....	7¢ lb. & 40% <sup>a</sup>
Xylose .....	50%
Zinc, blocks, pigs, dust..	1¼¢ lb.
ore, to 10% Zn .....	1½¢ lb.
10-20% .....	1½¢ lb.
20-25% .....	1½¢ lb.
25% & over .....	1½¢ lb.
Zinc chloride .....	1¾¢ lb.
oxide & leaded oxides (to 25% Pb), dry. ....	1¼¢ lb.
in oil or water .....	2¼¢ lb.
sulfate .....	¾¢ lb.
sulfide .....	3¢ lb.
Zirconium .....	25%
( <i>see also</i> Metals)	

## Appendix II

CENSUS OF VALUE OF U. S. CHEMICALS AND ALLIED PRODUCTS, 1923-29<sup>a</sup>  
(From *Census of Mfrs.*)

<i>Industry</i>	<i>1923</i>	<i>1925</i>	<i>1927</i>	<i>1929</i>
Total .....	\$2,472,610	\$2,651,375	\$2,855,979	\$3,289,289
Alcohol, ethyl, & distilled liquors.....	33,000	57,706	33,971	54,285
Ammunition & related products.....	51,509	41,707	45,602	43,809
Baking powder, yeast, & other leavening compounds .....	51,691	53,347 <sup>b</sup>	55,176 <sup>b</sup>	52,337
Blackening, stains, & dressings .....	25,822	25,055	22,548	24,682
Bluing .....	1,643	2,167	1,674	1,365
Bone black, carbon black, & lampblack	14,600	14,565	14,362	20,170
Candles .....	5,080	5,114	6,351	6,686
Chemicals not elsewhere classified <sup>c</sup> ...	630,870	547,003	548,536	738,048
Cleaning & polishing preparations ....	35,443	34,020	41,234	50,780
Compressed & liquefied gases .....	( <sup>d</sup> )	( <sup>d</sup> )	50,547	52,190
Druggists' preparations .....	79,143	95,420	110,309	123,778
Drug grinding .....	10,562	8,446	9,205	9,669
Explosives .....	79,029	69,669	72,490	72,540
Fertilizers .....	183,089	206,773	190,385	232,511
Fireworks .....	4,977	6,031	5,885	6,584
Glue & gelatin .....	24,366	25,764	31,196	32,458
Grease & tallow, excluding lubricating greases .....	48,634	51,442	56,280	61,608
Ink, printing .....	29,412	34,753	37,734	42,750
Ink, writing .....	6,107	6,084	5,342	4,595
Liquors, vinous .....	5,831	3,436	2,693	2,448
Mucilage, paste, & adhesives, excluding glue & rubber cement .....	( <sup>e</sup> )	9,853	7,945	6,638
Paints & varnishes .....	404,134	470,736	515,010	568,976
Patent or proprietary medicines & compounds .....	237,494	247,564	278,243	318,907
Perfumes, cosmetics & other toilet preparations .....	100,241	129,510	161,246	193,441
Rayon & allied products .....	( <sup>d</sup> )	88,061	109,888	149,546
Salt .....	36,837	34,253	34,329	37,869
Soap .....	276,403	278,273	287,060	310,192
Sulfuric, nitric, & mixed acids .....	24,405	23,307	23,555	( <sup>d</sup> )
Tanning materials, natural dyestuffs, mordants & assistants, sizes .....	35,972	34,784	35,677	39,836
Wood distillation & charcoal manufacture .....	29,695	25,283	27,630	29,594

<sup>a</sup> In thousands of dollars; <sup>b</sup> Revised, revision not carried into total; <sup>c</sup> For 1923 includes rayon, for 1923-25 compressed & liquefied gases, for 1929 sulfuric, nitric, and mixed acids; <sup>d</sup> Included in "Chemicals not elsewhere classified"; <sup>e</sup> No comparable statistics.

## Appendix III

CENSUS OF U. S. CHEMICAL INDUSTRY <sup>a</sup>(From *Census of Mfrs.*)

## Growth of Industry

	1923 <sup>b</sup>	1925 <sup>c</sup>	1927	1929
No. establishments .....	773	751	492	551
Av. no. wage earners .....	77,254	57,890	52,347	62,199
Wages .....	\$103,300,991	\$ 83,537,432	\$ 78,274,975	\$ 94,680,013
Cost of materials, containers, fuel, & bought power .....	\$328,596,621	\$282,712,468	\$296,677,164	\$363,576,811
Total value of products .....	\$655,274,829	\$570,310,106	\$572,090,732	\$738,048,386

## Value of Chemical Products

*Chemical Groups*

Acids .....	\$ 79,005,511	\$ 79,273,578	\$ 88,175,519	\$ 98,619,871
Nitrogen & fixed-nitrogen compounds .....	30,435,909	29,659,414	26,085,661	38,336,799
Sodium compounds .....	111,848,381	109,522,017	113,880,497	137,654,863
Potassium compounds .....	6,318,822	6,071,146	9,306,037	9,998,054
Aluminum compounds & alums	11,066,611	11,581,290	13,563,095	15,948,773
Coal-tar products .....	121,893,211	112,201,348	106,056,504	130,651,757
Plastics .....	102,229,807 <sup>d</sup>	34,575,068 <sup>e</sup>	28,202,865	39,734,426 <sup>e</sup>
Miscellaneous chemicals .....	205,411,310 <sup>f</sup>	192,851,350 <sup>e</sup>	235,941,261 <sup>e</sup>	310,245,384 <sup>e</sup>
Compressed & liquefied gases	53,384,029	55,532,616	( <sup>g</sup> )	( <sup>g</sup> )
Total chemicals, gross <sup>a</sup> ..	\$721,593,591	\$631,267,827 <sup>e</sup>	\$621,211,439 <sup>e</sup>	\$781,189,927 <sup>e</sup>

<sup>a</sup> Firms reporting products below \$5,000 value excluded, also such products as explosives, fertilizers, soap, wood distillation compounds, etc., which are treated as separate industries and will be found elsewhere in the Appendix; <sup>b</sup> Includes rayon, compressed & liquefied gases; <sup>c</sup> Includes compressed & liquefied gases; <sup>d</sup> Includes rayon; <sup>e</sup> Revised; <sup>f</sup> Includes \$16,729,233 worth of bleaching compounds which forms separate group in 15th Census; <sup>g</sup> Treated as separate industry beginning with 1927; <sup>h</sup> Includes other products not normally belonging to chemical industry.

# Appendix IV

## PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (From *Drug Chem. Mkts. & O.P.B. Reprtr.*)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Acetaldehyde .....	—	—	—	—	—	—	—	—
Acetanilide, tech., bbls. ....	— <sup>a</sup>	.27 <sup>b</sup>	.27 <sup>a</sup>	.27 <sup>b</sup>	.27 <sup>a</sup>	.26 <sup>b</sup>	.26 <sup>a</sup>	.20 <sup>b</sup>
Acetone, drs., c/1, wks. ....	.10 <sup>a</sup>	Nom. <sup>b</sup>	.25 <sup>a</sup>	.25 <sup>b</sup>	.15 <sup>a</sup>	.17 <sup>b</sup>	— <sup>a</sup>	.12 <sup>b</sup>
Acid, acetic, 28%, bbls. ....	2.25	3.17½	3.17½	3.38	3.12	3.38	3.12	3.00
anhydride, 85%, chys. ....	.37 <sup>a</sup>	.37 <sup>b</sup>	.38 <sup>a</sup>	.38 <sup>b</sup>	.43 <sup>a, d</sup>	.41 <sup>b, d</sup>	.41 <sup>a, d</sup>	.29 <sup>b, e</sup>
acetylsalicylic (aspirin), powd., bulk, bbls..	.70	1.00	.72½	1.05	.69	.72½	.70	.70
benzoic, tech., kegs .....	.55	.72	.65	.77	.65	.65	.57	.65
boric, cryst., bbls. ....	.11	.12½	.09½	.11	.08½	.09½	.08½	.08½
chloroacetic, bbls., wks. ....	— <sup>a</sup>	.30 <sup>b</sup>	.30 <sup>b</sup>	.30 <sup>b</sup>	.25 <sup>a</sup>	.25 <sup>b</sup>	.25 <sup>a</sup>	.25 <sup>b</sup>
chlorosulfonic, drs., wks. ....	.15 <sup>a</sup>	.15 <sup>b</sup>	.15 <sup>a</sup>	.15 <sup>b</sup>	.15 <sup>a</sup>	.15 <sup>b</sup>	.15 <sup>a</sup>	.15 <sup>b</sup>
chromic, 98%, drs. ....	.75 <sup>a</sup>	.40 <sup>b</sup>	.40 <sup>a</sup>	.40 <sup>b</sup>	.37 <sup>a</sup>	.37 <sup>b</sup>	.37 <sup>a</sup>	.37 <sup>b</sup>
citric, cryst., bbls. ....	.42½	.50	.47	.52	.45½	.48	.45½	.46
cresylic, 97-99%, pale, drs. ....	.56	1.00	.78	1.50	.62	.78	.54	.62
formic, 85%, tech., bbls. ....	.18 <sup>a, c</sup>	.15 <sup>b, c</sup>	.12	.15	.11	.13½	.10	.11
H <sub>2</sub> bbls. ....	.75	1.20	.75	.80	.72	.75	.68	.72
hydrochloric, 22°, tks. ....	1.35	1.75	1.75	1.75	1.75	1.75	1.75	1.75
lactic, 22°, dark, bbls. ....	.04 <sup>a</sup>	.04 <sup>b</sup>	.04½ <sup>a</sup>	.04½ <sup>b</sup>	.05½ <sup>a</sup>	.06 <sup>b</sup>	.05½ <sup>a</sup>	.05½ <sup>b</sup>
nitric, 42°, chys., c/1, wks. ....	5.25	6.50	5.25	5.25	5.25	5.75	5.75	6.25
oxalic, bbls., wks. ....	.11½	.17½	1¼	.13¼	.09½	.12	.10¼	.11
phosphoric, 50% tech., chys. ....	.08½ <sup>a</sup>	.07½ <sup>b</sup>	.07½	.08	.07	.07½	.07	.07
picric, kegs .....	.20	.20	.20	.20	.20	.20	.20	.30
salicylic, tech., bbls. ....	.22	.37	.33	.47	.33	.33	.33	.33
stearic, double-pressed, bags .....	.09½	.11½	.11¼	.14½	.11	.12¼	.13¼	.15¼
sulfuric, 60°, tks. ....	10.00 <sup>a</sup>	9.00 <sup>b</sup>	9.00	10.00	9.00	11.00	9.00	10.00
fuming (oleum) 20%, tks. ....	17.00	21.00	17.00	19.50	17.50	19.00	17.50	17.50
tannic, tech., bbls. ....	.35 <sup>a</sup>	.40 <sup>b</sup>	.40 <sup>a</sup>	.40 <sup>b</sup>	.35 <sup>a</sup>	.35 <sup>b</sup>	.35 <sup>a</sup>	.35 <sup>b</sup>
tartaric, U.S.P., cryst., powd., bbls. ....	.25	.31	.28	.36½	.25½	.28	.27	.29

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> 75%; <sup>d</sup> 90-95%; <sup>e</sup> 92-95%.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Acetaldehyde .....	.30 <sup>a</sup>	.24 <sup>b</sup>	.24	.24	.18½	.26	.18½	.21
Acetamide, tech., bbls. ....	.20 <sup>a</sup>	.20 <sup>b</sup>	.20	.20	.23	.24	.21	.24
Acetone, drs., c/1, wks. ....	.12 <sup>a</sup>	.12 <sup>b</sup>	.12	.12	.13	.15	.11	.16
Acid, acetic, 28%, bbls. ....	3.12	3.37½	3.38	3.38	3.38	3.88	3.88	3.88
anhydride, 92-95%, cbys. ....	.29 <sup>a</sup>	.29 <sup>b</sup>	.29	.29	.29	.35	.28	.35
acetylsalicylic (aspirin) powd., bulk, bbls....	.70	.85	.85	.85	.85	.85	.85	.85
benzoic, tech., kegs .....	.57	.57	.57	.57	.57	.60	.51	.60
boric, cryst., bbls. ....	.08	.08½	.08½	.08½	.08½	.11	.08½	.07½
chloroacetic, bbls., wks. ....	.25 <sup>a</sup>	.25 <sup>b</sup>	.18	.21	.18	.21	.18	.21
chlorosulfonic, drs., wks. ....	.15 <sup>a</sup>	.15 <sup>b</sup>	.15	.15	.15	.16	.04½	.05½
chromic, 99%, drs. extra .....	.37 <sup>a</sup>	.37 <sup>b</sup>	.25	.37	.25	.30	.17½	.23
citric, cryst., bbls. ....	.44½	.45½	.43½	.45½	.44½	.46	.46	.46
cresylic, 97-99%, pale, drs. ....	.55	.65	.60	.75	.65	.78	.62	.65
formic, 85% tech., bbls. ....	.10½	.11½	.10 <sup>a</sup>	.11 <sup>a</sup>	.11	.12	.10½	.12
H <sub>2</sub> , bbls. ....	.60	.68	.60	.68	.68	.68	.65	.68
hydrochloric, 22°, tks. ....	1.75	1.75	1.50	1.95	1.60	1.60	1.60	1.60
lactic, 22%, dark, bbls. ....	.05½ <sup>a</sup>	.05½ <sup>b</sup>	.05½	.05½	.04¾	.06	.04¾	.05¾
nitric, 42°, cbys., c/1, wks. ....	6.25	6.50	6.50	6.50	6.50	6.50	6.50	6.50
oxalic, bbls., wks. ....	.10½	.11	.11	.11½	.10¾	.11½	.11	.11¾
phosphoric, 50% tech., cbys. ....	.07	.08½	.08½	.08½	.08½	.08½	.08½	.08½
picric, kegs .....	.30	.30	.30	.45	.40	.50	.30	.50
salicylic, tech., bbls. ....	.27	.37	.27	.27	.27	.32	.33	.42
stearic, double-pressed, bags .....	.12	.15¾	.11½	.13¼	.11	.18½	.15¼	.18½
sulfuric, 60°, tks. ....	10.00	10.50	10.50	11.00	11.00	11.00	11.00	11.00
fuming (oleum) 20%, tks. ....	17.50	17.50	17.50	18.00	18.50	18.50	18.50	18.50
tannic, tech., bbls. ....	.35 <sup>a</sup>	.35 <sup>b</sup>	.30	.30	.30	.40	.30	.40
tartaric, U.S.P., cryst., powd., bbls. ....	.27½	.29	.29½	.37	.34½	.38	.38	.38½

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> 98%, drs.; <sup>d</sup> Cbys.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Alcohol, amyl (fusel oil), crude, drs. ....gal.	1.35 <sup>a</sup>	2.00 <sup>b</sup>	— <sup>a</sup>	4.30 <sup>b</sup>	1.85 <sup>a,c</sup>	2.80 <sup>b,c</sup>	2.50 <sup>a,c</sup>	2.00 <sup>b,c</sup>
butyl (normal), drs. ....lb.	.20 <sup>a</sup>	.20 <sup>b</sup>	.40 <sup>a</sup>	.45 <sup>b</sup>	.50 <sup>a,d</sup>	.26 <sup>b,d</sup>	.24 <sup>1/4 a,d</sup>	.19 <sup>1/2 b,d</sup>
ethyl, CD No. 5, drs., drs. extra ....gal.	.25	.40	.32	.45 <sup>1/2</sup>	.41	.53	.39	.53 <sup>1/2</sup>
U.S.P. 190 <sup>a</sup> , bbls. ....gal.	4.70 <sup>a</sup>	4.70 <sup>b</sup>	4.75 <sup>a</sup>	4.83 <sup>b</sup>	4.83 <sup>a</sup>	4.92 <sup>b</sup>	4.90 <sup>a</sup>	4.94 <sup>b</sup>
isopropyl, ref., drs. ....gal.	4.00 <sup>a</sup>	4.00 <sup>b</sup>	4.00 <sup>a</sup>	4.00 <sup>b</sup>	4.00 <sup>a,e</sup>	4.75 <sup>b,e</sup>	1.25 <sup>a,e</sup>	1.25 <sup>b,e</sup>
methyl (methanol), 95% tks. ....gal.	.50	1.13	.88	1.13	.65	.88	.58	.68
Alum, ammonia, lump, bbls., wks. ....cwt.	3.25	3.50	3.50	3.50	3.25	3.50	3.50	3.50
potash, lump, bbls., wks. ....cwt.	4.25 <sup>a</sup>	4.50 <sup>b</sup>	4.50 <sup>a</sup>	4.50 <sup>b</sup>	4.50 <sup>a</sup>	3.30 <sup>b</sup>	3.50 <sup>a</sup>	3.50 <sup>b</sup>
Aluminum chloride, anhyd., drs. ....lb.	.35 <sup>a</sup>	.20 <sup>b</sup>	.20 <sup>a</sup>	.20 <sup>b</sup>	.20 <sup>a</sup>	.20 <sup>b</sup>	.20 <sup>a</sup>	.20 <sup>b</sup>
hydroxide, light, bbls. ....lb.	.17 <sup>a</sup>	.18 <sup>b</sup>	.19 <sup>a</sup>	.18 <sup>b</sup>	.17 <sup>a</sup>	.17 <sup>b</sup>	.17 <sup>a</sup>	.17 <sup>b</sup>
stearate, bbls. ....lb.	.25 <sup>a</sup>	.25 <sup>b</sup>	.25 <sup>a</sup>	.25 <sup>b</sup>	.23 <sup>a</sup>	.24 <sup>b</sup>	.21 <sup>1/2 a</sup>	.22 <sup>b</sup>
sulfate, com., bags, c/l, wks. ....cwt.	1.50	1.60	1.40	1.50	1.35	1.40	1.40	1.40
p-Aminophenol, kegs ....lb.	1.25 <sup>a</sup>	1.10 <sup>b</sup>	1.40 <sup>a</sup>	1.25 <sup>b</sup>	1.15 <sup>a</sup>	1.16 <sup>b</sup>	1.10 <sup>a</sup>	1.10 <sup>b</sup>
Ammonia, anhyd., clys. ....lb.	.30 <sup>a</sup>	.30 <sup>b</sup>	.30 <sup>a</sup>	.30 <sup>b</sup>	.30 <sup>a</sup>	.30 <sup>b</sup>	.30 <sup>a</sup>	.13 <sup>b</sup>
aqua 26°, drs. ....lb.	.06 <sup>3/4</sup>	.07 <sup>1/2</sup>	.06 <sup>3/4</sup>	.07	.06 <sup>1/2</sup>	.07	.03 <sup>1/2</sup>	.06 <sup>1/2</sup>
Ammonium carbonate, tech., cks. ....lb.	.06 <sup>1/2 a,e</sup>	.09 <sup>1/2 b</sup>	.09 <sup>1/2 a</sup>	.10 <sup>b</sup>	.08 <sup>1/2 a</sup>	.08 <sup>1/2 b</sup>	.08 <sup>3/4 a</sup>	.08 <sup>3/4 b</sup>
chloride, gray, bbls., wks. ....lb.	.07 <sup>3/4 a</sup>	.07 <sup>3/4 b</sup>	.08 <sup>3/4 a</sup>	.08 <sup>3/4 b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.07 <sup>3/4 a</sup>	.07 <sup>3/4 b</sup>
nitrate, tech., cks. ....lb.	.06 <sup>a</sup>	.07 <sup>b</sup>	.07 <sup>1/2 a</sup>	.07 <sup>1/2 b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>
phosphate, tech., powd., bbls. ....lb.	.17 <sup>a</sup>	.15 <sup>b</sup>	.15 <sup>a</sup>	.15 <sup>b</sup>	.18 <sup>a</sup>	.18 <sup>b</sup>	.18 <sup>a</sup>	.18 <sup>b</sup>
sulfate, double bags, f.a.s. N. Y. ....cwt.	2.55	3.65	2.75	3.65	2.40	3.00	2.50	3.07 <sup>1/2</sup>
Amyl acetate, tech., drs. ....gal.	1.77 <sup>a</sup>	2.35 <sup>b</sup>	4.25 <sup>a</sup>	4.65 <sup>b</sup>	2.80 <sup>a</sup>	3.25 <sup>b</sup>	2.70 <sup>a</sup>	2.45 <sup>b</sup>
Aniline oil, drs. ....lb.	.12 <sup>1/2</sup>	.17	.16	.16 <sup>1/2</sup>	.16	.16	.16	.16
salt, bbls. ....lb.	.21	.24	.22	.24	.21	.24	.22	.24
Anthracene, 80%, bbls. ....lb.	.75	.75	.75	.75	.65	.75	.60	.65
Anthraquinone, subl., bbls. ....lb.	1.35 <sup>a</sup>	1.30 <sup>b</sup>	1.30 <sup>a</sup>	1.30 <sup>b</sup>	1.00 <sup>a</sup>	1.00 <sup>b</sup>	1.00 <sup>a</sup>	.95 <sup>b</sup>
Antimony sulfide, golden, bbls. ....lb.	.16 <sup>a</sup>	.19 <sup>b</sup>	.21 <sup>a</sup>	.21 <sup>b</sup>	.21 <sup>a</sup>	.21 <sup>b</sup>	.20 <sup>a</sup>	.15 <sup>b</sup>
Antipyrine, bulk, cans ....lb.	2.10 <sup>a</sup>	2.30 <sup>b</sup>	3.00 <sup>a</sup>	2.35 <sup>b</sup>	2.10 <sup>a</sup>	1.90 <sup>b</sup>	1.75 <sup>a</sup>	1.68 <sup>b</sup>
Argols, crude 30% cks. ....lb.	.07	.10	.06 <sup>1/2</sup>	.07	.05 <sup>1/2</sup>	.06 <sup>1/2</sup>	.05 <sup>1/2</sup>	.05 <sup>1/2</sup>
Arsenic red, kegs, cases ....lb.	.11	.13	.13	.15 <sup>1/2</sup>	.15	.15	.12	.15
white, kegs ....lb.	.05 <sup>1/2</sup>	.15 <sup>1/2</sup>	.09 <sup>3/4</sup>	.16	.06	.13 <sup>1/2</sup>	.03 <sup>1/2</sup>	.06 <sup>1/4</sup>
Barium carbonate, precip., bags, wks. ....ton	60.00 <sup>a</sup>	78.00 <sup>b</sup>	68.00 <sup>a</sup>	85.00 <sup>b</sup>	68.00 <sup>a</sup>	63.00 <sup>b</sup>	54.00 <sup>a</sup>	50.00 <sup>b</sup>

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> 10% impurities; <sup>d</sup> Tks., wks.; <sup>e</sup> 98-99%; <sup>f</sup> Bbls.

# PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Alcohol, amyl (fusel oil), 10% impurities, drs. gal.	1.25 <sup>a</sup>	1.30 <sup>b</sup>	1.35	1.69	1.75 <sup>c</sup>	2.25 <sup>c</sup>	1.67 <sup>c</sup>	1.67 <sup>c</sup>
butyl (normal), tks., wks. ....lb.	.17½ <sup>a</sup>	.18½ <sup>b</sup>	.18½	.19½	.17½	.19	.16½	.17½
ethyl, CD No. 5, drs., drs. extra ....gal.	.33	.33	.29	.50	.43	.50	.48	.51
U.S.P., 190 <sup>c</sup> , bbls. ....gal.	4.75 <sup>a</sup>	4.75 <sup>b</sup>	3.70	3.70	2.65	3.70	2.69½	2.75
isopropyl, ref. (90-91%), drs. ....gal.	1.00 <sup>a</sup>	1.00 <sup>b</sup>	1.00	1.00	1.00	1.25	1.00	1.30
methyl (methanol), 95% tks. ....gal.	.55	.80	.45	.80	.40	.55	.48	.55
Alum, ammonia, lump, bbls., wks. ....cwt.	3.35	3.50	3.25	3.45	3.25	3.25	3.25	3.60
potash, lump, bbls., wks. ....cwt.	3.50 <sup>a</sup>	3.50 <sup>b</sup>	3.10	3.50	3.10	3.20	3.00	3.50
Aluminum chloride, anhyd., drs. ....lb.	.35 <sup>a</sup>	.35 <sup>b</sup>	.35	.35	.35	.40	.05	.20
hydroxide, 96% light, bbls. ....lb.	.17 <sup>a</sup>	.17 <sup>b</sup>	.17	.17	.17	.17	.17	.18
stearate, bbls. ....lb.	.23 <sup>a</sup>	.23 <sup>b</sup>	.23	.23	.18	.24	.25	.26
sulfate, com., bags, c/1, wks. ....cwt.	1.40	1.40	1.35	1.40	1.40	1.40	1.40	1.40
p-Aminophenol, kegs ....lb.	1.15	1.15	1.15	1.15	1.15	1.15	.99	1.15
Aminonia, anhyd., cyls. ....lb.	.13 <sup>a</sup>	.11 <sup>b</sup>	.10	.13½	.13½	.14	.14	.14½
aqua 25°, drs., delv. ....lb.	.03½ <sup>a</sup>	.03 <sup>b</sup>	.02½	.03	.03	.03	.03½	.03½
Ammonium carbonate, tech., cases ....lb.	.08½ <sup>a</sup>	.08½ <sup>b</sup>	.08½	.08½	.08½	.09	.09	.12
chloride, gray, bbls., wks. ....lb.	.07½ <sup>a</sup>	.07 <sup>b</sup>	.05½	.07	5.25 <sup>a</sup>	5.75 <sup>a</sup>	5.25 <sup>a</sup>	5.75 <sup>a</sup>
nitrate, tech., cks. ....lb.	.06 <sup>a</sup>	.06 <sup>b</sup>	.06	.06	.06	.10	.06	.10
phosphate, tech., powd., bbls. ....lb.	.18 <sup>a</sup>	.18 <sup>b</sup>	.18	.18	.18	.18	.12½	.13
sulfate, double bags, f.a.s. N. Y. ....cwt.	2.50	2.90	2.30	2.55	2.35	2.45	2.00	2.35
Amyl acetate, tech., drs. ....gal.	1.75 <sup>a</sup>	1.60 <sup>b</sup>	—	—	—	—	.23 <sup>c</sup>	.24 <sup>c</sup>
Aniline oil, drs. ....lb.	.15	.16	.15	.15½	.15½	.16½	.15	.16½
salt, bbls. ....lb.	.22	.24	.24	.24	.24	.24	.24	.24
Anthracene, 80% bbls. ....lb.	.60	Nom.	—	—	—	—	—	—
Anthraquinone, subl., bbls. ....lb.	.90 <sup>a</sup>	.90 <sup>b</sup>	.90	.90	.90	1.00	.80	.90
Antimony sulfide, golden, bbls. ....lb.	.15 <sup>a</sup>	.15 <sup>b</sup>	.16	.20	.16	.20	.16	.20
Antipyrine, bulk, cans ....lb.	1.68 <sup>a</sup>	1.65 <sup>b</sup>	1.65 <sup>a</sup>	1.58 <sup>b</sup>	1.53 <sup>a</sup>	1.45 <sup>b</sup>	1.60 <sup>a</sup>	2.30 <sup>b</sup>
Argols, crude 30% cks. ....lb.	.03	.05½	.03	.08	.08	.08	.08	.08
Arsenic red, kegs, cases ....lb.	.10½	.12	.10½	.10½	.10½	.11	.09	.11
white, kegs ....lb.	.03½	.03½	.03½	.04	.03½	.04	.04	.04½
Barium carbonate, precip., bags, wks. ....ton	50.00 <sup>a</sup>	47.50 <sup>b</sup>	47.50	47.50	47.00	57.00	57.00	60.00

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> From pentane, tks., wks., per lb.; <sup>d</sup> Per cwt.; <sup>e</sup> Per lb.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Barium chloride, cryst., bags	50.00	110.00	82.00	90.00	61.00	90.00	56.00	68.00
Barytes, floated, bbls., wks.	23.00	26.00	25.00	28.00	22.00	26.00	22.00	23.00
Benzaldehyde, tech., clys.	.45	.65	.65	.75	.70	.75	.70	.70
Benzene, 90%, tks., wks.	.27	.27	.21	.32	.21	.23	.21	.24
Benzidine base, dry, bbls.	.80	.95	.80	.85	.78	.80	.72	.78
Benzyl chloride, 95-97%, drs.	.25	.37	.35	.40	.35	.35	.30	.35
Bismuth subnitrate, powd., bbls.	1.75	2.65	2.65	2.90	2.15	2.90	2.00	3.35
Blanc fixe, dry, bbls., c/1, wks.	.04	.04½	.04	.04½	.03½	.04½	.03½	.04½
Bleaching powder, drs., c/1, wks., contr.	1.60	2.00	1.25	2.25	1.50	1.90	1.90	2.00
Borax, powd., bags	.05½	.05½	.05½	.05½	.04½	.05½	.04½	.04½
Bordeaux mixture, powd., bbls.	.13*	.20*	.20*	.20*	.11½*	.11½*	.11½*	.11½*
Bromine, purif., cases	.25	.27	.25	.30	.27	.44	.47	.47
Butyl acetate, drs.	—	—	—	—	—	2.40 <sup>b</sup>	2.27*	1.84 <sup>b</sup>
Cadmium sulfide, boxes	1.60*	1.50 <sup>b</sup>	1.50*	1.75 <sup>b</sup>	1.50* <sup>c</sup>	1.50 <sup>b,c</sup>	1.50* <sup>c</sup>	1.20 <sup>b,c</sup>
Caffeine, alkaloid, cans, cases	3.50	4.25	3.60	4.00	3.40	4.00	3.45	3.75
Calcium acetate (lime acetate), bags, c/1, cwt.	1.75	3.50	3.50	4.00	3.00	4.00	2.75	3.25
arsenate, bbls.	.10	.16	.12	.18	.08*	.13*	.07*	.08*
chloride, flake, drs., c/1, wks.	30.50*	30.50*	30.50*	30.50 <sup>b</sup>	30.50*	27.00 <sup>b</sup>	27.00*	27.00 <sup>b</sup>
cyanamide, bulk, c/1, wks.	2.75*	2.25 <sup>b</sup>	3.25*	2.25 <sup>b</sup>	1.90*	1.90 <sup>b</sup>	1.87½*	1.90 <sup>b</sup>
phosphate, monobasic, bbls.	.17*	.06½ <sup>b</sup>	.07*	.07 <sup>b</sup>	.07*	.07 <sup>b</sup>	.07*	.07 <sup>b</sup>
Camphor, jap. ref., slabs, cases	.76	.94	.83	.91	.66½	.83	.65	.77½
Carbon bisulfide, drs.	.06*	.06*	.06*	.06 <sup>b</sup>	.06*	.06 <sup>b</sup>	.05½*	.05½ <sup>b</sup>
black, bags, wks.	.10½	.24	.07	.17	.05½	.12	.06	.09
tetrachloride, drs.	.09½	.10½	.09	.10	.06½	.09	.06½	.07
Cellulose acetate, cases	—	—	—	1.75 <sup>b</sup>	1.75*	1.75 <sup>b</sup>	2.00*	1.55 <sup>b</sup>
Chlorine, liq., tks., wks., contr.	.05	.08	.05	.05½	.04	.05½	.04	.04½
Chlorobenzene (mono), drs., c/1, wks.	.10 <sup>b</sup>	.10 <sup>b</sup>	.10*	.10 <sup>b</sup>	.08*	.08 <sup>b</sup>	.07½*	.07½ <sup>b</sup>
Chloroform, tech., drs.	.22*	.32*	.32*	.32*	.32*	.32*	.28*	.22*
Cobalt acetate, bbls.	1.10*	1.12 <sup>b</sup>	1.10*	1.12 <sup>b</sup>	1.00*	1.10 <sup>b</sup>	1.00*	1.00 <sup>b</sup>
linoleate, solid, bbls.	.52*	.53 <sup>b</sup>	.53*	.51 <sup>b</sup>	.20*	.45 <sup>b</sup> *	.45*	.43*
Cocaine hydrochloride, gran., cans	7.00	7.00	7.00	7.00	7.00	7.00	7.50	8.00

\* June price; <sup>b</sup> Dec. price; <sup>c</sup> Cases; <sup>d</sup> Drs.; <sup>e</sup> Paste.



PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Barium chloride, cryst., bags .....	60.00	65.00	50.00	61.00	54.00 <sup>c</sup>	65.00 <sup>c</sup>	63.00 <sup>c</sup>	69.00 <sup>c</sup>
Barytes, floated, bbls., wks. ....	23.00	23.00	23.00	23.00	23.00	24.00	23.00	24.00
Benzaldehyde, tech., drs., wks. ....	.65	.70	.65	.65	.65	.70	.60	.65
Benzene, 90%, tks., wks. ....	.24	.25	.21	.23	.23	.23	.23	.23
Benzidine base, drv., bbls. ....	.69	.72	.70	.70	.70	.74	.70	.74
Benzyl chloride, 95-97%, drs. ....	.30	.30	.30	.30	.25 <sup>d</sup>	.25 <sup>d</sup>	.25 <sup>d</sup>	.25 <sup>d</sup>
Bismuth subnitrate, powd., bbls. ....	2.70	3.35	2.05	2.70	1.60	2.30	1.60	1.60
Blanc fixe, drv., bbls., c/l, wks. ....	.03 3/4	.04	.04	.04 1/4	80.00 <sup>e</sup>	90.00 <sup>e</sup>	75.00 <sup>e</sup>	90.00 <sup>e</sup>
Bleaching powder, drs., c/l, wks., contr. ....	2.00	2.00	2.00	2.25	2.25	2.25	2.00	2.25
Borax, powd., bags .....	.04	.04 1/4	.03 3/4	.04	.02 1/2	.03 3/4	.02 1/2	.02 3/4
Bordeaux mixture, 16% powd., bbls. ....	.14 1/2 <sup>a</sup>	.11 <sup>b</sup>	.11	.11	.10 1/2	.12	.10 1/2	.14
Bromine, purif., cases .....	.47	.47	.45	.47	.45 <sup>a</sup>	.45 <sup>b</sup>	.45 <sup>a</sup>	.45 <sup>b</sup>
Buryl acetate, drs. ....	1.40	2.28	1.45	1.57	1.35 <sup>c</sup>	1.55 <sup>c</sup>	.181 <sup>a,c</sup>	.186 <sup>a,c</sup>
Cadmium sulfide, boxes .....	1.50 <sup>a</sup>	1.50 <sup>b</sup>	1.35	1.50	1.35	2.00	.75	1.75
Caffeine, alkaloid, cans, cases .....	3.25	3.50	3.05	3.25	2.80	3.05	2.75	2.80
Calcium acetate (lime acetate), bags, c/l, .cwt. ....	3.25	3.50	3.50	3.50	3.50	3.50	4.50	4.50
arsenate, drs. ....	.07	.08	.06 1/2	.07 1/2	.06 <sup>a</sup>	.09 <sup>a</sup>	.07 <sup>b</sup>	.09 <sup>a</sup>
chloride, flake, drs., c/l, wks. ....	27.00 <sup>a</sup>	27.00 <sup>b</sup>	27.00	27.00	25.00	27.00	22.75	25.00
cyanamide, bulk, c/l, wks. ....	1.90 <sup>a</sup>	1.82 1/2 <sup>b</sup>	1.67 1/2	1.82 1/2	1.67 1/2	1.75	2.00	2.00
phosphate, monobasic, bbls. ....	.07 <sup>a</sup>	.07 <sup>b</sup>	.09	.09	.07	.08	.07	.08
Camphor, Jap. ref., slabs, cases .....	.71 1/2	.80	.60	.72	.57	.65	.59	.64
Carbon bisulfide, drs. ....	.05 1/2 <sup>a</sup>	.05 1/2 <sup>b</sup>	.05 1/2	.05 1/2	.05 1/2	.06	.05 1/2	.06
black, bags, wks. ....	.08	.08	.06 1/2	.06 1/2	.12 <sup>1</sup>	.12 <sup>1</sup>	.12 <sup>1</sup>	.12 <sup>1</sup>
tetrachloride, drs. ....	.06 1/4	.06 1/4	.06 1/4	.06 1/4	.07 <sup>1</sup>	.07 1/2 <sup>1</sup>	.06 1/4 <sup>1</sup>	.07 1/2 <sup>1</sup>
Cellulose acetate, bags .....	1.35	1.65	1.25	1.40	1.20	1.25	1.20	1.20
Chlorine, liq., tks., wks., contr. ....	.04	.04	.04	.05 1/2	.03 1/2	.03 1/2	.02 1/2	.03
Chlorobenzene (mono), drs., wks. ....	.07 <sup>a</sup>	.07 <sup>b</sup>	.07	.07	.07	.07	.08 1/2	.10 1/2
Chloroform, tech., drs. ....	.20 <sup>a</sup>	.20 <sup>b</sup>	.20	.20	.20	.22	.16	.20
Cobalt acetate, bbls. ....	1.00 <sup>a</sup>	1.00 <sup>b</sup>	1.00 <sup>a</sup>	.85 <sup>b</sup>	.85 <sup>a</sup>	.85 <sup>b</sup>	.85 <sup>a</sup>	.85 <sup>b</sup>
linoleate, paste, bbls. ....	.42 <sup>a</sup>	.42 <sup>b</sup>	.41 <sup>a</sup>	.43 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>
Cocaine hydrochloride, gran., cans .....	8.00	8.00	8.00	8.50	8.50	8.50	8.50	8.50

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Bbls., wks.; <sup>d</sup> Tech.; <sup>e</sup> Per ton; <sup>f</sup> Tks., wks.; <sup>g</sup> Per cwt.; <sup>h</sup> Bbls., c/l, wks.; <sup>i</sup> Cases, l/c/l; <sup>j</sup> Delv.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Codeine sulfate, cans	4.80	5.85	5.85	6.80	6.75	7.75	7.75	7.75
Copper carbonate, bbls.	.19 <sup>a</sup>	.20 <sup>b</sup>	.19½ <sup>a</sup>	.16½ <sup>b</sup>	.16 <sup>a</sup>	.16½ <sup>b</sup>	.16½ <sup>a</sup>	.16¾ <sup>b</sup>
sulfate (blue vitriol), 99%, bbls.	5.00	6.25	4.65	6.50	4.50	4.95	4.40	4.75
Coumarin, makers, cans	3.00	4.00	4.00	4.50	3.25	4.50	3.10	3.25
Cream of tartar, powd., bbls.	.23	.26½	.23	.26	.20	.23	.20½	.21½
Cresote oil (tar acid), 25%, d.	.23	.26¼	.30	.35	.34	.34	.26	.34
Cresol, U.S.P., drs.	.12	.14	.25	.27	.18	.24	.18	.24½
o-Cresol, drs.	.16 <sup>a</sup>	.18 <sup>b</sup>	.30 <sup>a</sup>	.28 <sup>b</sup>	.18 <sup>a</sup>	.18 <sup>b</sup>	.18 <sup>a</sup>	.18 <sup>b</sup>
p-Dichlorobenzene, bbls., wks.	.17 <sup>a</sup>	.17 <sup>b</sup>	.17 <sup>a</sup>	.17 <sup>b</sup>	.17 <sup>a</sup>	.17 <sup>b</sup>	.17 <sup>a</sup>	.17 <sup>b</sup>
Dimethylamine, drs.	—	—	—	—	— <sup>a</sup>	.280 <sup>b</sup>	.280 <sup>a</sup>	.260 <sup>b</sup>
Dimethylaniline, drs.	.32	.41	.41	.42	.33	.39	.30	.33
Dinitrobenzene, bbls.	.20	.24	.18	.20	.15	.19	.14	.15
Dinitrophenol, bbls.	.33 <sup>a</sup>	.33 <sup>b</sup>	.40 <sup>a</sup>	.38 <sup>b</sup>	.40 <sup>a</sup>	.32 <sup>b</sup>	.32 <sup>a</sup>	.31 <sup>b</sup>
Diphenylamine, bbls.	.52	.60	.48	.52	.48	.48	.48	.48
Diphenylguanidine, bbls.	—	—	1.15 <sup>a</sup>	1.10 <sup>b</sup>	1.10 <sup>a</sup>	1.10 <sup>b</sup>	.95 <sup>a</sup>	.95 <sup>b</sup>
Ethyl acetate, tech., tks.	.60	.80	.80	.95	.90	1.05	.85	.90
chloride, cyls.	.55 <sup>a</sup>	.50 <sup>b</sup>	.50 <sup>a</sup>	.50 <sup>b</sup>	.35 <sup>a</sup>	.26 <sup>b</sup>	.26 <sup>a</sup>	.26 <sup>b</sup>
Ethylene chlorohydrin, anhyd., drs.	—	—	.75 <sup>a</sup>	.75 <sup>b</sup>	.75 <sup>a</sup>	.75 <sup>b</sup>	.75 <sup>a</sup>	.75 <sup>b</sup>
dibromide, drs.	—	—	.60 <sup>a</sup>	.60 <sup>b</sup>	.60 <sup>a</sup>	.70 <sup>b</sup>	.70 <sup>a</sup>	.70 <sup>b</sup>
glycol	—	1.00 <sup>b</sup>	.65 <sup>a</sup>	.65 <sup>b</sup>	.65 <sup>a</sup>	.65 <sup>b</sup>	.50 <sup>a</sup>	.30 <sup>b</sup>
Ferric chloride, tech., cryst., bbls.	.08½ <sup>a</sup>	.10 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.07½ <sup>a</sup>	.05 <sup>b</sup>
Ferrous sulfate (copperas), bulk, c/1, wks., ton	17.00 <sup>a</sup>	18.00 <sup>b</sup>	17.00	21.00	15.00	17.00	8.50	12.00
Formaldehyde, U.S.P., bbls., wks.	.08	.16	.10¾	.16	.08¾	.11	.08¾	.09
Furfural, drs.	.50 <sup>a</sup>	.25 <sup>b</sup>	.25 <sup>a</sup>	.25 <sup>b</sup>	.25 <sup>a</sup>	.23 <sup>b</sup>	.22 <sup>a</sup>	.23 <sup>b</sup>
G salt, paste, bbls.	.65 <sup>a</sup>	.65 <sup>b</sup>	.65 <sup>a</sup>	.60 <sup>b</sup>	.60 <sup>a</sup>	.60 <sup>b</sup>	.50 <sup>a</sup>	— <sup>b</sup>
Glycerin, dynamite, drs.	.12½	.18	.14	.17¾	.15	.18½	.18	.25
Hexamethylenetetramine, U.S.P., drs.	.67 <sup>a</sup>	.95 <sup>b</sup>	.93 <sup>a</sup>	.75 <sup>b</sup>	.75 <sup>a</sup>	.75 <sup>b</sup>	.60 <sup>a</sup>	.60 <sup>b</sup>
Hydrogen peroxide, 25 vol., bbls.	—	.10 <sup>b</sup>	.10 <sup>a</sup>	.10 <sup>b</sup>	.36 <sup>a, c</sup>	.32 <sup>b, c</sup>	.34 <sup>a, c</sup>	.32 <sup>b, c</sup>
Indigo, synth., 20% paste, drs.	.35 <sup>a</sup>	.25 <sup>b</sup>	.26 <sup>a</sup>	.26 <sup>b</sup>	.23 <sup>a</sup>	.23 <sup>b</sup>	.15 <sup>a</sup>	.14 <sup>b</sup>
Iodine, resubl., kegs	3.80	4.50	4.50	4.55	4.40	4.65	4.65	4.65
Lead acetate, white, cryst., bbls., wks.	.10½ <sup>a</sup>	.12 <sup>b</sup>	.14 <sup>a</sup>	.14 <sup>b</sup>	.14½ <sup>a</sup>	.15½ <sup>b</sup>	.14½ <sup>a</sup>	.14½ <sup>b</sup>

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> 100 vol., cbys.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Codeine sulfate, cans .....	7.75	7.75	7.75	8.75	8.25	8.75	8.25	9.50
Copper carbonate, bbls. ....	.16% <sup>a</sup>	.16% <sup>b</sup>	.16%	.16%	.16	.17 1/4	.13	.25
sulfate (blue vitriol), 99%, bbls. ....	4.40	4.90	4.80	5.00	5.05 <sup>c</sup>	5.50 <sup>c</sup>	5.50 <sup>c</sup>	7.00 <sup>c</sup>
Coumarin, makers, cans .....	2.50	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Cream of tartar, powd., bbls. ....	.20 1/2	.21	.20 1/2	.27 3/4	.26 <sup>d</sup>	.27 <sup>d</sup>	.26 1/4 <sup>d</sup>	.28 <sup>d</sup>
Cresote oil (tar acid), 25%, drs. ....	.26	.29	.28	.29	.17 <sup>e</sup>	.19 <sup>e</sup>	.15 <sup>e</sup>	.19 <sup>e</sup>
Cresol, U.S.P., drs. ....	.17 1/2	.18	.17 1/2	.17 1/2	.17 1/2	.20	.14	.17
o-Cresol, drs. ....	.18 <sup>a</sup>	.17 <sup>a</sup>	.18	.18	.18	.28	.18	.28
p-Dichlorobenzene, bbls., wks. ....	.17 <sup>a</sup>	.17 <sup>b</sup>	.17	.17	.17	.20	.17	.20
Dimethylamine, drs. ....	2.60 <sup>a</sup>	2.60 <sup>b</sup>	2.60	2.60	2.62	2.62	2.62	2.62
Dimethylaniline, drs. ....	.30	.32	.30	.32	.30	.32	.26	.32
Dinitrobenzene, bbls. ....	.15	.16	.15	.15 1/2	.15 1/2	.16 1/2	.15	.16 1/2
Dinitrophenol, bbls. ....	.31 <sup>a</sup>	.31 <sup>b</sup>	.31	.31	.31	.32	.31	.32
Diphenylamine, bbls. ....	.48	.48	.45	.48	.45	.47	.40	.47
Diphenylguanidine, bbls. ....	.85 <sup>a</sup>	.85 <sup>b</sup>	—	—	.40	.72	.30	.40
Ethyl acetate, tech., tks. ....	.72	.85	.72	.85	.75 <sup>c</sup>	1.05 <sup>c</sup>	.108 <sup>c</sup>	.122 <sup>c</sup>
chloride, drs. ....	.22 <sup>a</sup>	.22 <sup>b</sup>	.22	.22	.22	.22	.22	.22
Ethylene chlorohydrin, anhyd., drs. ....	.75 <sup>a</sup>	.75 <sup>b</sup>	.75	.75	.75	.75 <sup>a</sup>	.75 <sup>a</sup>	.85 <sup>a</sup>
dibromide, drs. ....	.70 <sup>a</sup>	.70 <sup>b</sup>	.70	.70	.70	.70	.70	.70
glycol, drs., wks. ....	.30 <sup>a</sup>	.30 <sup>b</sup>	.30	.30	.25	.40	.25	.30
Ferric chloride, tech., cryst., bbls. ....	.07 1/2 <sup>a</sup>	.07 1/2 <sup>b</sup>	.07 1/2	.07 1/2	.07 1/2	.09	.05	.09
Ferrous sulfate (copperas), bulk, c/l, wks., ton	11.00	13.00	13.00	13.00	13.00	13.00	13.00	14.00
Formaldehyde, U.S.P., bbls., wks. ....	.11 1/4	.11 1/4	.08 3/4	.11 1/4	.08 1/2	.09	.08 1/2	.10
Furfural, drs. ....	.17 1/2 <sup>a</sup>	.17 1/2 <sup>b</sup>	.17 1/2	.17 1/2	.17 1/2	.19 1/4	.17 1/2	.19 1/4
G salt, paste, bbls. ....	.50 <sup>a</sup>	.50 <sup>b</sup>	.50	.50	.50	.52	.45	.52
Glycerin, dyanmate, drs. ....	.21	.29	.17	.25	.11 1/4	.15	.10 1/4	.12 1/2
Hexamethylenetetramine, U.S.P., drs. ....	.60 <sup>a</sup>	.60 <sup>b</sup>	.62	.80	.56	.62	.48	.58
Hydrogen peroxide, 100 vol., chys. ....	.31 <sup>a</sup>	.30 <sup>b</sup>	.22	.30	.24	.26	.24	.26
Indigo, synth., 20% paste, drs. ....	.14 <sup>a</sup>	.14 <sup>b</sup>	.14	.14	.15	.18	.15	.18
Iodine, resubli., kegs .....	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Lead acetate, white, cryst., bbls., wks. ....	14.00 <sup>a</sup>	14.00 <sup>b</sup>	13.00	14.00	13.00	13.50	14.00	14.50

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Bbls., c/l, wks.; <sup>d</sup> U.S.P.; <sup>e</sup> Grade 1, tks.; <sup>f</sup> 85%; <sup>g</sup> Per lb.; <sup>h</sup> 40%, chys.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Lead arsenate, paste, bbls. ....	.08 <sup>a</sup>	.13 <sup>b</sup>	.12 <sup>a</sup>	.12 <sup>b</sup>	.10 <sup>a</sup>	.10 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>
carbonate, basic (white lead), dry, cks. ....	.06½	.08¾	.08½	.09¾	.08¾	.11	.10½	.12
oxide (litharge), Am., com. powd., cks. ....	.0992	.1093	.1093	.1174	.10	.12½	.11	.13¼
oxide, red (red lead), dry, cks. ....	.08	.104	.104	.114	.10½	.12¾	.11½	.13¾
Lithopone, dom., bbls., c/l. ....	.06	.06½	.06	.07¼	.06	.07	.05½	.06½
Logwood, 51° bbls. ....	.08 <sup>a</sup>	.08 <sup>b</sup>	.07½ <sup>a</sup>	.12½ <sup>b</sup>	.09 <sup>a</sup>	.08½ <sup>b</sup>	.08½ <sup>a</sup>	.08½ <sup>b</sup>
Magnesium carbonate, tech., bags ....	.06 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.06¾ <sup>a</sup>	.06¾ <sup>b</sup>
chloride, flake, drs., wks. ....	32.00 <sup>a</sup>	34.00 <sup>b</sup>	36.00 <sup>a</sup>	36.00 <sup>b</sup>	36.00 <sup>a,c</sup>	36.00 <sup>b,c</sup>	36.00 <sup>a,c</sup>	36.00 <sup>b,c</sup>
oxide, U.S.P., light, bbls. ....	.53 <sup>a</sup>	.45 <sup>b</sup>	.45 <sup>a</sup>	.42 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>
sulfate (Epsom salt), tech., import., bags ....	.85	1.20	1.10	1.20	1.10	1.30	1.30	1.30
Manganese chloride, cks. ....	.09½ <sup>a</sup>	.09½ <sup>b</sup>	.09½ <sup>a</sup>	.09½ <sup>b</sup>	.09½ <sup>a</sup>	.09½ <sup>b</sup>	.06 <sup>a</sup>	.06 <sup>b</sup>
dioxide (peroxide), 80-84%, bbls. ....	80.00 <sup>a</sup>	80.00 <sup>b</sup>	80.00 <sup>a</sup>	80.00 <sup>b</sup>	80.00 <sup>a</sup>	85.00 <sup>b</sup>	80.00 <sup>a</sup>	80.00 <sup>b</sup>
Menthol, import., cases ....	5.25	10.50	7.75	19.50	10.75	14.25	7.50	12.75
Mercuric chloride (corrosive sublimate), kegs lb. ....	.76 <sup>a</sup>	1.02 <sup>b</sup>	1.02 <sup>a</sup>	1.02 <sup>b</sup>	.98 <sup>a</sup>	.98 <sup>b</sup>	1.10 <sup>a</sup>	1.16 <sup>b</sup>
Mercurous chloride (calomel), kegs ....	.82	1.25	1.25	1.25	1.10	1.22	1.22	1.45
Mercury ..... flasks	48.00	74.00	60.00	75.00	59.00	78.00	77.00	91.00
Methyl acetate, drs. .... gal.	—	—	—	—	— <sup>a</sup>	—	— <sup>a</sup>	.95 <sup>b</sup>
Methyl acetone, drs. .... gal.	.50 <sup>a</sup>	.70 <sup>b</sup>	.95 <sup>a</sup>	1.20 <sup>b</sup>	.75 <sup>a</sup>	.75 <sup>b</sup>	.75 <sup>a</sup>	.83 <sup>b</sup>
chloride, cys. .... lb.	— <sup>a</sup>	.50 <sup>b</sup>	.50 <sup>a</sup>	.50 <sup>b</sup>	.50 <sup>a</sup>	.50 <sup>b</sup>	.50 <sup>a</sup>	.60 <sup>b</sup>
Morphine sulfate, cans .... oz.	4.90	5.35	5.35	6.30	6.25	7.25	7.25	7.25
Naphtha, solvent, water-white, drs., wks. .... gal.	.25	.27	.27	.27	.24	.28	.24	.35
Naphthalene, flake, bbls. .... lb.	.05¾	.06½	.06	.09½	.04½	.06½	.05	.06
α-Naphthol, crude, bbls. .... lb.	.87	1.00	.60	.87	.60	.60	.60	.65
β-Naphthol, crude, bbls. .... lb.	.22	.29	.20	.26	.22	.25	.22	.22
α-Naphthylamine, bbls. .... lb.	.27	.30	.27	.38	.35	.35	.35	.35
β-Naphthylamine, tech., kegs .... lb.	.95	1.00	.72	.95	.65	.72	.63	.65
Nickel salt, single, bbls. .... lb.	.10	.12	.10½	.10½	.10½	.11½	.10½	.11½
Niter cake, bulk, wks. .... ton	6.00 <sup>a</sup>	6.50 <sup>b</sup>	6.50 <sup>a</sup>	5.50 <sup>b</sup>	5.50 <sup>a</sup>	5.50 <sup>b</sup>	4.50 <sup>a</sup>	4.50 <sup>b</sup>
p-Nitrobenzene, kegs .... lb.	.73	.77	.70	.75	.65	.70	.53	.62
Nitrobenzene, drs. .... lb.	.09½	.10	.09½	.10	.09	.09	.09	.09½
Nitrocellulose .... lb.	—	—	—	—	—	—	—	—

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> C/l.

# PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Lead arsenate, drs., wks. ....	.14 <sup>a</sup> , <sup>e</sup>	.15½ <sup>b</sup> , <sup>e</sup>	.13½	.15½	.13	.15	.13	.15
carbonate, basic (white lead), dry, cks. ....	.09%	.10%	.08½	.09%	.08¼	.08½	.08¼	.09
oxide (litharge), Am., com. powd., cks. ....	.10½	.11¾	.08½	.10¾	.08½	.09	.08¾	.10¼
red (red lead), dry, cks. ....	.11	.12¼	.09¾	.11¼	.09½	.10	.09¾	.11¼
Lithopone, dom., bags, c/1 .....	.05%	.05%	.05%	.05%	.05¼	.05¼	.05¼	.05¼
Logwood, 51°, bbls. ....	.08¼ <sup>a</sup>	.08¼ <sup>b</sup>	.08¼	.08¼	.08¼	.08½	.08¼	.08½
Magnesium carbonate, tech., bags .....	.06½ <sup>a</sup>	.06½ <sup>b</sup>	.06	.06½	.06	.06½	.06	.06½
chloride, flake, drs., c/1, wks. ....	37.00 <sup>a</sup>	37.00 <sup>b</sup>	37.00	37.00	37.00	37.00	36.00	36.00
oxide, USP, light, bbls. ....	.42 <sup>a</sup>	.42 <sup>b</sup>	.42	.42	.42	.42	.42	.42
sulfate (Epsom salt), tech., bbls., c/1 .....	2.00 <sup>a</sup>	1.75 <sup>b</sup>	1.75	2.00	1.70	1.75	1.70	1.90
Manganese chloride, cks. ....	.08 <sup>a</sup>	.08 <sup>b</sup>	.08	.08	.08	.08½	.08	.08½
dioxide (peroxide), drs. ....	.05 <sup>a</sup>	.04½ <sup>b</sup>	.04½	.05	—	—	.04½	.06
Menthol, import., cases .....	4.30	7.00	3.95	4.75	4.00	6.15	4.40	6.00
Mercuric chloride (corrosive sublimate), kegs. lb. ....	1.16 <sup>a</sup>	1.27 <sup>b</sup>	1.58 <sup>a</sup>	1.65 <sup>b</sup>	1.65 <sup>a</sup>	1.65 <sup>b</sup>	1.65 <sup>a</sup> , <sup>d</sup>	1.65 <sup>b</sup> , <sup>d</sup>
Mercurous chloride (calomel), kegs .....	1.45	1.59	1.59	2.05	2.05	2.05	2.05	2.05
Mercury .....	87.00	100.00	100.00	128.50	120.00	132.50	120.00	125.00
Methyl acetate, drs. ....	.95 <sup>a</sup>	.95 <sup>b</sup>	.95	.95	.95	.95	.95	.95
acetone, drs. ....	.63 <sup>a</sup>	.88 <sup>b</sup>	.75	.88	.68	.90	.83	.85
chloride, cyl. ....	.55 <sup>a</sup>	.55 <sup>b</sup>	.55	.55	.55	.60	.45	.60
Morphine sulfate, cans .....	7.25	7.25	7.25	8.25	7.75	8.25	7.75	8.75
Naphtha, solvent, water-white, drs., wks. ....	.35	.35	.35	.35	.30	.35	.30	.30
Naphthalene, flake, bbls. ....	.04¾	.06½	.04½	.05	.04½	.05	.04½	.05
α-Naphthol, tech., bbls. ....	.60	.65	.60	.60	.60	.60	.60	.60
β-Naphthol, tech., bbls. ....	.22	.22	.22	.22	.22	.22	.22	.22
α-Naphthylamine, bbls. ....	.35	.35	.32	.35	.32	.32	.32	.32
β-Naphthylamine, tech., kegs .....	.63	.65	.65	.65	.65	.65	.60	.65
Nickel salt, single, bbls. ....	.10½	.10½	.10½	.10½	.10½	.13	.13	.13
Niter cake, bulk, wks. ....	4.50 <sup>a</sup>	4.50 <sup>b</sup>	4.50 <sup>a</sup>	4.50 <sup>b</sup>	13.00	14.00	12.00	18.00
p-Nitroaniline, kegs .....	.44	.53	.52	.52	.52	.55	.51	.51
Nitrobenzene, drs. ....	.09	.09½	.09	.09½	.08½ <sup>a</sup>	.09½ <sup>a</sup>	.09 <sup>a</sup>	.09 <sup>a</sup>
Nitrocellulose, regular, drs., wks. ....	.40	.40	.40	.40	.40 <sup>a</sup>	Nom. <sup>a</sup>	.25 <sup>a</sup>	.36 <sup>a</sup>

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Redist.; <sup>d</sup> Drs., kegs; <sup>e</sup> C/1, 1/c/1, wks.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
<i>p</i> -Nitrochlorobenzene, drs., wks. ....lb.	.25 <sup>a</sup>	.25 <sup>b</sup>	.21 <sup>a</sup>	.20 <sup>b</sup>	.20 <sup>a</sup>	.20 <sup>b</sup>	.20 <sup>a</sup>	.20 <sup>b</sup>
<i>o</i> -Nitrotoluene, drs. ....lb.	.10	.15	.09	.10	.10	.12	.10	.20
<i>p</i> -Nitrotoluene, bbls. ....lb.	.60 <sup>a</sup>	.75 <sup>b</sup>	.50 <sup>a</sup>	.55 <sup>b</sup>	.47 <sup>a</sup>	.42 <sup>b</sup>	.38 <sup>a</sup>	.25 <sup>b</sup>
Oil, China wood (tung), bbls. ....lb.	.11 <sup>1</sup> / <sub>4</sub>	.14 <sup>3</sup> / <sub>4</sub>	.14 <sup>1</sup> / <sub>2</sub>	.40	.12	.21 <sup>1</sup> / <sub>2</sub>	.12 <sup>1</sup> / <sub>2</sub>	.15 <sup>1</sup> / <sub>2</sub>
linseed, c/1 .....gal.	.64	.90	.83	1.17	.90	1.13	.121 <sup>c</sup>	1.20
peppermint, natural, cases .....lb.	1.85 <sup>a</sup>	2.60 <sup>b</sup>	2.65 <sup>a</sup>	3.25 <sup>b</sup>	4.00 <sup>a</sup>	9.00 <sup>b</sup>	13.25 <sup>a</sup>	28.00 <sup>b</sup>
pine, destructively dist., drs., bbls. ....lb.	—	—	—	—	—	—	—	—
steam-dist., bbls. ....gal.	.80	1.20	.65	.85	.60	.68	.60	.65
soybean, crude, bbls. ....lb.	.08 <sup>3</sup> / <sub>4</sub>	.11 <sup>1</sup> / <sub>4</sub>	.10 <sup>3</sup> / <sub>8</sub>	.13	.11 <sup>1</sup> / <sub>4</sub>	.13 <sup>1</sup> / <sub>2</sub>	.13	.13 <sup>1</sup> / <sub>2</sub>
spearmint, U.S.P., cases .....lb.	3.00 <sup>a</sup>	2.45 <sup>b</sup>	2.50 <sup>a</sup>	2.40 <sup>b</sup>	2.70 <sup>a</sup>	4.35 <sup>b</sup>	2.75 <sup>a</sup>	13.00 <sup>b</sup>
Turkey red, bbls. ....lb.	.09 <sup>a</sup>	.09 <sup>b</sup>	.11 <sup>a</sup>	.11 <sup>b</sup>	.11 <sup>a</sup>	.11 <sup>b</sup>	.11 <sup>a</sup>	.11 <sup>b</sup>
Optium gum, U.S.P., cases .....lb.	6.00 <sup>a</sup>	6.75 <sup>b</sup>	8.00 <sup>a</sup>	8.00 <sup>b</sup>	9.00 <sup>a</sup>	12.00 <sup>b</sup>	12.00 <sup>a</sup>	12.00 <sup>b</sup>
Paraldehyde, drs. ....lb.	.75 <sup>a</sup>	.35 <sup>b</sup>	.35 <sup>a</sup>	.35 <sup>b</sup>	.43 <sup>a</sup>	.48 <sup>b</sup>	.48 <sup>a</sup>	.48 <sup>b</sup>
Paris green, bulk .....lb.	.20	.26	.25	.37	.26	.32	.19 <sup>a</sup>	.19 <sup>b</sup>
Phenol, U.S.P., drs. ....lb.	.11	.35	.25	.58	.23	.37	.21	.23
<i>p</i> -Phenylenediamine, bbls. ....lb.	1.50 <sup>a</sup>	1.50 <sup>b</sup>	1.35	1.40	1.30	1.40	1.25 <sup>a</sup>	1.20 <sup>b</sup>
Phosphate rock, Fla. pebble, 68%, f.o.b. mines .ton	2.50	3.25	2.50	3.25	2.10	3.25	2.10	2.85
Tennessee, 72% .....ton	4.00 <sup>a</sup>	3.00 <sup>b</sup>	3.25 <sup>a</sup>	5.50 <sup>b</sup>	5.50 <sup>a</sup>	5.50 <sup>b</sup>	5.50 <sup>a</sup>	5.50 <sup>b</sup>
Phthalic anhydride, tech., bbls. ....lb.	.35	.40	.25	.40	.21	.30	.18	.21
Porash, manure salts, 20%, import., bulk .....ton	9.50 <sup>a</sup>	10.55 <sup>b</sup>	10.55 <sup>a</sup>	9.44 <sup>1</sup> / <sub>2</sub> <sup>b</sup>	9.50 <sup>a</sup>	10.55 <sup>b</sup>	11.00 <sup>a</sup>	11.35 <sup>b</sup>
Potassium bichromate, cryst., cks. ....lb.	.09 <sup>1</sup> / <sub>4</sub>	.10 <sup>1</sup> / <sub>4</sub>	.09 <sup>1</sup> / <sub>2</sub>	.11 <sup>1</sup> / <sub>2</sub>	.08 <sup>1</sup> / <sub>2</sub>	.09 <sup>1</sup> / <sub>2</sub>	.08 <sup>1</sup> / <sub>4</sub>	.08 <sup>3</sup> / <sub>8</sub>
bisulfate, kegs .....lb.	.40 <sup>a</sup>	.22 <sup>b</sup>	.22 <sup>a</sup>	.22 <sup>b</sup>	.22 <sup>a</sup>	.22 <sup>b</sup>	.22 <sup>a</sup>	.22 <sup>b</sup>
bromide, U.S.P., bbls. ....lb.	.23 <sup>a</sup>	.26 <sup>b</sup>	.26 <sup>a</sup>	.26 <sup>b</sup>	.29 <sup>a</sup>	.48 <sup>b</sup>	.48 <sup>a</sup>	.48 <sup>b</sup>
carbonate, 80-85% calc., cks. ....lb.	.04 <sup>1</sup> / <sub>4</sub>	.06 <sup>1</sup> / <sub>2</sub>	.05 <sup>1</sup> / <sub>4</sub>	.06 <sup>3</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>	.06	.05 <sup>1</sup> / <sub>4</sub>	.06 <sup>1</sup> / <sub>4</sub>
chloride, cryst., bbls. ....lb.	— <sup>a</sup>	.04 <sup>b</sup>	.04 <sup>b</sup>	.04 <sup>b</sup>	.04 <sup>a</sup>	.04 <sup>b</sup>	.04 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>2</sub> <sup>b</sup>
cyanide, cases .....lb.	.50 <sup>a</sup>	.65 <sup>b</sup>	.45 <sup>a</sup>	.65 <sup>b</sup>	.65 <sup>a</sup>	.60 <sup>b</sup>	.58 <sup>a</sup>	.52 <sup>b</sup>
ferricyanide (red prussiate), cks. ....lb.	.85 <sup>a</sup>	.92 <sup>b</sup>	.70 <sup>a</sup>	.50 <sup>b</sup>	.37 <sup>a</sup>	.39 <sup>b</sup>	.37 <sup>a</sup>	.37 <sup>b</sup>
ferrocyanide (yellow prussiate), cks. ....lb.	.23	.41	.25	.38	.16 <sup>1</sup> / <sub>2</sub>	.22	.17 <sup>1</sup> / <sub>4</sub>	.19
hydroxide (caustic potash), 88-92% .....lb.	.05	.06 <sup>1</sup> / <sub>2</sub>	.06	.08 <sup>1</sup> / <sub>4</sub>	.06 <sup>1</sup> / <sub>4</sub>	.07 <sup>1</sup> / <sub>4</sub>	.07 <sup>1</sup> / <sub>4</sub>	.07 <sup>1</sup> / <sub>4</sub>
muriate, 80-85%, basis 80%, bulk .....ton	32.00	35.55	31.09 <sup>1</sup> / <sub>2</sub>	35.55	31.09 <sup>1</sup> / <sub>2</sub>	34.55	34.55	34.90
nitrate (saltpeter), cryst. ....lb.	.07 <sup>1</sup> / <sub>4</sub>	.08 <sup>3</sup> / <sub>8</sub>	.07	.07 <sup>3</sup> / <sub>8</sub>	.07	.07 <sup>1</sup> / <sub>2</sub>	.07	.07 <sup>1</sup> / <sub>2</sub>

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Per lb.; <sup>d</sup> Single bbls.; <sup>e</sup> Tech.; <sup>f</sup> Arsenic basis, kegs; <sup>g</sup> 70-75%.

# PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
<i>p</i> -Nitrochlorobenzene, drs., wks. ....lb.	.32 <sup>a</sup>	.32 <sup>b</sup>	.32	.32	.32	.32	.23	.26
<i>o</i> -Nitrotoluene, drs. ....lb.	.13	.16	.13	.16	.16	.16	.16	.16
<i>p</i> -Nitrotoluene, bbls. ....lb.	.30 <sup>a</sup>	.30 <sup>b</sup>	.25	.30	.30	.30	.29	.31
Oil, China wood (tung), bbls. ....lb.	.11½	.19	.14¾	.32	.14	.17	.13½	.15½
linseed, c/1 .....lb.	.102	.123	.094	.11½	.11½	.104	.10	.163
peppermint, natural, cases .....lb.	14.00 <sup>a</sup>	5.00 <sup>b</sup>	3.55 <sup>a</sup>	3.20 <sup>b</sup>	3.15 <sup>a</sup>	3.35 <sup>b</sup>	2.85 <sup>a</sup>	3.35 <sup>b</sup>
pine, destructively dist., drs., bbls. ....lb.	—	—	.63	.63	.63	.64	.63	.64
steam-dist., bbls. ....gal.	.60	.70	.67	.72	.66	.69	.63	.66
soybean, crude, bbls. ....lb.	.11¾	.14	.11¾	.12½	.12	.12½	.11	.12½
spearmint, U.S.P., cases .....lb.	6.25 <sup>a</sup>	4.75 <sup>b</sup>	3.65 <sup>a</sup>	4.30 <sup>b</sup>	4.10 <sup>a</sup>	4.25 <sup>b</sup>	4.05 <sup>a</sup>	4.65 <sup>b</sup>
Turkey red, single bbls. ....lb.	.11 <sup>a</sup>	.11 <sup>b</sup>	.11	.11	—	.11	.11	.12
Opium gum, U.S.P., cases .....lb.	12.00 <sup>a</sup>	12.00 <sup>b</sup>	12.00 <sup>a</sup>	12.00 <sup>b</sup>	12.00 <sup>a</sup>	12.00 <sup>b</sup>	12.00 <sup>a</sup>	12.00 <sup>b</sup>
Paraldehyde, tech., drs. ....lb.	.30 <sup>a</sup>	.26 <sup>b</sup>	.26	.29	.20½	.28	.20½	.28
Paris green, arsenic basis, kegs .....lb.	.19 <sup>a</sup>	.19 <sup>b</sup>	.19	.19	.17	.23	.23	.25
Phenol, U.S.P., drs. ....lb.	.17	.22	.16	.18	.12½	.17	.12½	.14¾
β-Phenylendiamine, bbls. ....lb.	1.20 <sup>a</sup>	1.20 <sup>b</sup>	1.15	1.20	1.15	1.20	1.15	1.20
Phosphate rock, Fla. pebble, 68% f.o.b. mines, ton	2.85	3.25	3.00	3.15	3.00	3.10	3.10	3.10
Tennessee, 72% .....ton	5.50 <sup>a</sup>	5.50 <sup>b</sup>	5.00	5.50	5.00	5.00	5.00	5.00
Phthalic anhydride, tech., bbls. ....lb.	.18	.18	.18	.18	.18	.18	.16	.18
Potash, manure salts, 20%, import, bulk .....ton	11.35 <sup>a</sup>	12.40 <sup>b</sup>	12.40	12.40	12.40	12.40	12.40	12.50
Potassium bichromate, cryst., cks. ....lb.	.08	.08½	.08	.08½	.08	.09	.09	.09
bisulfate, kegs .....lb.	.30 <sup>a</sup>	.30 <sup>b</sup>	.30	.30	.30	.30	.30	.30
bromide, U.S.P., bbls. ....lb.	.48 <sup>a</sup>	.48 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>	.42 <sup>a</sup>	.42 <sup>b</sup>
carbonate, 80-85% calc., cks. ....lb.	.05¼	.06	.05½	.05½	.05½	.05¾	.05¾	.05¾
chloride, cryst., bbls. ....lb.	.05¼ <sup>a</sup>	.05¾ <sup>b</sup>	.05½	.05½	.05½	.05½	.05½	.05½
cyanide, cases .....lb.	.55 <sup>a</sup>	.55 <sup>b</sup>	.55	.55	.55	.57½	.55	.57½
ferricyanide (red prussiate), kegs .....lb.	.37 <sup>a,c</sup>	.39 <sup>b,d</sup>	.37½	.39	.37	.38	.37	.40
ferrocyanide (yellow prussiate), cks. ....lb.	.17½	.19	.18	.18	.18	.18½	.18½	.21
hydroxide (caustic potash), 88-92% .....lb.	.07½	.07½	.07½	.07½	.07½	.07½	.06½	.07½
muriate, 80-85%, basis 80%, bulk .....ton	34.90	36.40	36.40	36.40	36.40	36.40	36.40	36.75
nitrate (saltpeter), cryst. ....lb.	.07½	.07½	.07½	.07½	.07½	.07½	.07½	.07½

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Cks.; <sup>d</sup> Bags.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Potassium permanganate, U.S.P., drs. ....lb.	.13	.17	.15 $\frac{3}{4}$	.27	.12 $\frac{1}{2}$	.15	.14 $\frac{1}{2}$	.15
sulfate, 90%, bags .....ton	41.10	45.67	39.30	45.67	41.26 $\frac{1}{2}$	45.85	45.85	45.85
Pyridine, drs. ....gal.	1.75 <sup>a</sup>	1.75 <sup>b</sup>	4.00 <sup>a</sup>	4.00 <sup>b</sup>	4.00 <sup>a</sup>	3.80 <sup>b</sup>	4.50 <sup>a</sup>	4.15 <sup>b</sup>
Pyrites, Span., 48-50% S, c.i.f., bulk .....unit	.11 $\frac{1}{2}$	.13	.11 $\frac{1}{2}$	.11 $\frac{1}{2}$	.11 $\frac{1}{2}$	.12	.11 $\frac{1}{2}$	.12
Quinine sulfate, dom., tins .....oz.	.50	.60	.50	.50	.50	.50	.50	.50
R salt, bbls., wks. ....lb.	.50 <sup>a</sup>	.55 <sup>b</sup>	.55 <sup>a</sup>	.55 <sup>b</sup>	.49 <sup>a</sup>	.49 <sup>b</sup>	.45 <sup>a</sup>	.45 <sup>b</sup>
Resorcinol, tech., cans .....lb.	1.25	1.50	1.35	1.50	1.25	1.40	1.25	1.35
Rochelle salt, cryst., boxes .....lb.	.16 $\frac{1}{2}$	.19 $\frac{1}{2}$	.19 $\frac{1}{2}$	.21	.20	.21	.20	.20
Rosin, F grade, 280 lb. bbls. ....bbl.	6.20 <sup>a</sup>	6.35 <sup>b</sup>	6.15 <sup>a</sup>	5.60 <sup>b</sup>	6.00 <sup>a</sup>	7.55 <sup>b</sup>	10.15 <sup>a</sup>	13.95 <sup>b</sup>
Saccharin, sol., cans .....lb.	1.85	2.00	1.85	1.85	1.75	1.85	1.75	1.75
Silver nitrate, U.S.P., bottles .....oz.	.47 $\frac{1}{2}$ <sup>a</sup>	.42 $\frac{1}{2}$ <sup>b</sup>	.44 $\frac{1}{2}$ <sup>a</sup>	.44 <sup>b</sup>	.45 <sup>a</sup>	.45 $\frac{3}{8}$ <sup>b</sup>	.45 $\frac{1}{2}$ <sup>a</sup>	.46 $\frac{3}{8}$ <sup>b</sup>
Sodium arsenite, 8-lb. material, drs., wks. ....gal.	—	—	—	—	1.20 <sup>a</sup>	1.00 <sup>b</sup>	1.00 <sup>a</sup>	1.00 <sup>b</sup>
benzoate, U.S.P., bbls. ....lb.	.50	.65	.65	.65	.62	.65	.50	.62
bicarbonate, bbls., wks. ....cwt.	1.75	2.00	1.75	2.15	1.75	1.75	1.90	1.90
bichromate, cks., wks. ....lb.	.06 $\frac{7}{8}$	.07 $\frac{1}{8}$	.07 $\frac{1}{8}$	.08 $\frac{1}{4}$	.06 $\frac{1}{2}$	.07 $\frac{1}{2}$	.06 $\frac{1}{4}$	.06 $\frac{3}{8}$
bromide, gran., bbls. ....lb.	.15	.18	.18	.21	.19	.43	.38	.47
carbonate (sal soda), bbls., wks. ....cwt.	1.10	1.60	1.10	1.10	1.10	1.10	1.10	1.10
(soda ash), 58% light, bags .....cwt.	1.50	1.80	1.48	1.75	1.38	1.38	1.38	1.38
cyanide, dom., 96-98%, cases .....lb.	.19	.26	.19	.21	.17	.21	.18	.20
ferrocyanide (yellow prussiate), bbls., wks..lb.	.16	.23 $\frac{1}{2}$	.11 $\frac{1}{2}$	.18 $\frac{1}{4}$	.09	.11 $\frac{1}{2}$	.09 $\frac{3}{4}$	.10 $\frac{1}{4}$
hydroxide (caustic soda), 76%, wks. ....cwt.	3.45	3.90	3.20	3.26	3.10	3.10	3.10	3.10
hyposulfite, tech., regular cryst., bbls. ....cwt.	2.85	2.85	2.50	2.50	2.35	2.75	2.35	2.40
nitrate, 95%, bags .....cwt.	2.25	2.90	2.40	2.70	2.37 $\frac{1}{2}$	2.65	2.44	2.69
nitrite, 96-98%, bbls. ....lb.	.06	.09 $\frac{1}{2}$	.07 $\frac{1}{4}$	.08 $\frac{1}{4}$	.08	.09 $\frac{1}{2}$	.09	.09 $\frac{1}{2}$
phosphate, di-, tech., bbls. ....lb.	.03 $\frac{1}{2}$ <sup>a</sup>	.03 $\frac{1}{2}$ <sup>b</sup>	.03 $\frac{1}{2}$	.03 $\frac{1}{2}$	.03 $\frac{1}{4}$	.03 $\frac{1}{2}$	.03 $\frac{1}{4}$	.03 $\frac{1}{4}$
tri-, tech., bbls. ....lb.	.05 $\frac{1}{4}$ <sup>a</sup>	.04 $\frac{1}{2}$ <sup>b</sup>	.04 $\frac{1}{4}$ <sup>a, c</sup>	.04 $\frac{1}{2}$ <sup>b, c</sup>	.03 $\frac{1}{4}$ <sup>a</sup>	.03 $\frac{3}{8}$ <sup>b</sup>	.03 $\frac{1}{4}$ <sup>a</sup>	3.90 <sup>b, d</sup>
salicylate, U.S.P., kegs .....lb.	.32 <sup>a</sup>	.47 <sup>b</sup>	.47 <sup>a</sup>	.40 <sup>b</sup>	.40 <sup>a</sup>	.40 <sup>b</sup>	.40 <sup>a</sup>	.40 <sup>b</sup>
silicate (water glass), 40°, tks., wks. ....cwt.	.72 $\frac{1}{2}$	.85	.72 $\frac{1}{2}$	.72 $\frac{1}{2}$	.75	.75	.75	.75
60°, drs., wks. ....cwt.	1.75	2.20	1.60	1.75	1.60	1.60	1.60	1.60
sulfate (Glauber's salt), dom., bbls., wks..cwt.	.75	1.00	.85	1.30	.85	1.00	.75	.85
anhyd. (salt cake), ground, bbls., wks..ton	17.00	25.00	22.00	25.00	17.00	23.00	18.00	22.00

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> C/I, bbls.; <sup>d</sup> Per cwt.



PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high	low	high	low	high	low	high
Potassium permanganate, U.S.P., drs. ....lb.	.14½	.14½	.14	.15	.15	.16	.16	.16
sulfate, 90%, bags .....ton	45.85	47.30	47.30	47.30	47.30	47.30	47.30	47.75
Pyridine, drs. ....g.l.	4.50 <sup>a</sup>	3.00 <sup>b</sup>	1.50	3.00	1.50	1.50	1.50	1.75
Pyrites, Span., 48-50% S, c.i.f., bulk .....unit	.11½	.12	.12	.13	.13	.13	.13	.13
Quinine sulfate, dom., tins .....oz.	.45 <sup>a</sup>	.50	.40	.40	.40	.40	.40	.40
R salt, bbls., wks. ....lb.	.45 <sup>a</sup>	.45 <sup>b</sup>	.45	.45	.45	.46	.44	.46
Resorcinol, tech., cans .....lb.	1.25	1.25	1.25	1.25	1.25	1.35	1.15	1.25
Rochelle salt, cryst., boxes .....lb.	.20	.20	.20	.23	.23	.23	.23	.23
Rosin, F grade, 280 lb. bbls. ....bbl.	14.40 <sup>a</sup>	12.60 <sup>b</sup>	8.50	13.20	8.65	10.10	8.40	9.27
Saccharin, sol., cans .....lb.	1.75	1.75	1.75	1.75	1.70	1.70	1.70	1.70
Silver nitrate, U.S.P., bottles .....oz.	.44% <sup>a</sup>	.37% <sup>b</sup>	.39% <sup>a</sup>	.40% <sup>b</sup>	.41% <sup>a</sup>	.40% <sup>b</sup>	.37% <sup>a,c</sup>	.35% <sup>b,c</sup>
Sodium arsenite, drs. ....gal.	—	—	1.00	1.00	—	—	1.00	1.50
benzoate, U.S.P., bbls. ....lb.	.50	.50	.50	.50	.50	.50	.45	.50
bicarbonate, bbls., wks. ....cwt.	1.90	1.90	1.90	1.90	1.90	2.00	2.00	2.00
bichromate, cks., wks. ....lb.	.06% <sup>a</sup>	.06½	.06% <sup>a</sup>	.06% <sup>a</sup>	.06% <sup>a</sup>	.07	.07	.07
bromide, gran., bbls. ....lb.	.40	.45	.42	.42	.42	.42	.42	.42
carbonate (sal soda), bbls., wks. ....cwt.	.90	1.10	.90	.90	—	—	1.00	1.00
(soda ash), 58% light, bags .....cwt.	1.32½	1.38	1.32½	1.32½	1.32	1.32	1.32	1.32
cyanide, dom., 96-98%, cases .....lb.	.18	.18	.18	.19	.17	.17	.17	.17
ferrocyanide (yellow prussiate), bbls., wks..lb.	.10	.11¾	.11% <sup>a</sup>	.12% <sup>a</sup>	.11	.12% <sup>a</sup>	.11% <sup>a</sup>	.11½
hydroxide (caustic soda), 76%, wks. ....cwt.	3.00	3.00	3.00	3.00	2.90	2.90	2.90	2.90
hyposulfite, tech., regular cryst., bbls. ....cwt.	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
nitrate, 95% bags .....cwt.	2.33	2.72	2.25	2.75	2.10	2.40	2.07	2.22½
nitrite, 96-98%, bbls. ....lb.	.08½	.09	.07½	.08½	.07% <sup>a</sup>	.07% <sup>a</sup>	.07% <sup>a</sup>	.07% <sup>a</sup>
phosphate, di-, tech., bbls. ....lb.	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>	.03% <sup>a</sup>
tri-, tech., bbls. ....cwt.	3.90 <sup>a</sup>	3.90 <sup>b</sup>	3.90 <sup>a</sup>	3.90 <sup>b</sup>	3.90 <sup>a</sup>	3.90 <sup>b</sup>	3.90	4.00
salicylate, U.S.P., kegs .....lb.	.37 <sup>a</sup>	.47 <sup>b</sup>	.47 <sup>a</sup>	.47 <sup>b</sup>	.47 <sup>a</sup>	.47 <sup>b</sup>	.47 <sup>a</sup>	.47 <sup>b</sup>
silicate (water glass), 40°, tks., wks. ....cwt.	.65	.70	.60	.65	.65	.70	.70	.70
60°, drs., wks. ....cwt.	1.60	1.65	1.60	1.60	1.65	1.65	1.65	1.65
sulfate (Glauber's salt), dom., bbls., wks..ton	.70	.90	.70	.85	.70	.70	.70	.70
anhyd. (salt cake), ground, bbls., wks..ton	20.00	20.00	21.00	21.00	21.00	21.00	21.00	25.00

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Vials.

PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1922		1923		1924		1925	
	low	high	low	high	low	high	low	high
Sodium sulfide, 62% solid, drs., wks. ....lb.	.03 3/4	.03 3/4 <sup>b</sup>	.04 1/2 <sup>a</sup>	.30 1/2 <sup>b</sup>	.03 1/2 <sup>a</sup>	.03 <sup>b</sup>	.04 <sup>a</sup>	.04 1/4 <sup>b</sup>
sulfite, cryst., bbls. ....lb.	.03 1/2	.03 3/4	.03 1/2	.03 1/2	.03 1/2	.03 1/2	.03 1/2	.03 1/2
Strontium nitrate, bbls., wks. ....lb.	.12 <sup>a</sup>	.11 <sup>b</sup>	.11 1/2 <sup>a</sup>	.11 1/2 <sup>b</sup>	.10 <sup>a</sup>	.10 <sup>b</sup>	.08 1/2 <sup>a</sup>	.08 <sup>b,c</sup>
Strychnine sulfate, U.S.P., cryst. powd. ....oz.	.76 <sup>a</sup>	.84 <sup>b</sup>	.84 <sup>a</sup>	.68 <sup>b</sup>	.43 1/2 <sup>a</sup>	.57 1/2 <sup>b</sup>	.54 <sup>a</sup>	.42 <sup>b</sup>
Sulfur, crude (brimstone), f.o.b. mines .....ton	14.00	15.00	14.00	14.00	14.00	15.00	14.00	17.00
chloride, red, drs., wks. ....lb.	.05 <sup>a</sup>	.05 1/2 <sup>b</sup>	.05 <sup>a</sup>	.06 <sup>b</sup>	.06 <sup>a</sup>	.06 <sup>b</sup>	.05 1/2 <sup>a</sup>	.05 <sup>b</sup>
dioxide, cysls. ....lb.	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>	.08 <sup>a</sup>	.08 <sup>b</sup>
Superphosphate, 16%, bulk, wks. ....ton	7.50	10.50	7.50	10.00	7.00	9.50	.60 <sup>d</sup>	.63 1/2 <sup>d</sup>
Tankage, conc., bulk, f.o.b. Chicago .....unit	2.25	4.25	2.50	4.25	2.50	3.25	2.90	3.25
Terpineol, C.P., drs. ....lb.	.50 <sup>a</sup>	.55 <sup>b</sup>	.50 <sup>a</sup>	.50 <sup>b</sup>	.48 <sup>a</sup>	.45 <sup>b</sup>	.35 <sup>a</sup>	.30 <sup>b</sup>
Thiocarbamide, bbls. ....lb.	— <sup>a</sup>	.35 <sup>b</sup>	.28 <sup>a</sup>	.28 <sup>b</sup>	.27 <sup>a</sup>	.27 <sup>b</sup>	.24 <sup>a</sup>	.24 <sup>b</sup>
Thymol, bottles ....lb.	3.90	4.75	3.00	4.00	2.90	5.50	3.65	5.00
Tin, cryst., bbls. ....lb.	.27 1/2	.32 1/2	.30	.37 1/2	.31 1/2	.39	.37	.43
tetrachloride, drs., wks. ....lb.	.21 1/2 <sup>a</sup>	.21 1/2 <sup>b</sup>	.26 <sup>a</sup>	.27 1/2 <sup>b</sup>	.24 1/2 <sup>a</sup>	.31 1/2 <sup>b</sup>	.31 1/2 <sup>a</sup>	.36 <sup>b</sup>
Titanium dioxide ....lb.	—	—	—	—	—	—	—	—
Toluene (toluol), tks., wks. ....gal.	.30	.30	.26	.30	.26	.26	.26	.35
Toluidine, mixed, drs., wks. ....lb.	.30 <sup>a</sup>	.30 <sup>b</sup>	.31 <sup>a</sup>	.31 <sup>b</sup>	.31 <sup>a</sup>	.31 <sup>b</sup>	.31 <sup>a</sup>	.31 <sup>b</sup>
o-Toluidine, drs. ....lb.	.13	.20	.13	.18	.12 1/2	.17	.17	.25
p-Toluidine, cks. ....lb.	.78	1.10	.78	.95	.72	.90	.55	.75
Triacetin, drs., wks. ....lb.	—	—	— <sup>a</sup>	.45 <sup>b</sup>	.37 1/2 <sup>a</sup>	.37 1/2 <sup>b</sup>	.37 1/2 <sup>a</sup>	.35 <sup>b</sup>
Tricresyl phosphate ....lb.	—	—	—	—	—	—	—	—
Turpentine, gum spirits, bbls. ....gal.	.82 1/2	1.64	.93	1.61	.81	1.04	.87	1.16
Urea, pharm., cases ....lb.	.40 <sup>a</sup>	.40 <sup>b</sup>	.40 <sup>a</sup>	.30 <sup>b</sup>	.30 <sup>a</sup>	.18 <sup>b</sup>	.18 <sup>a</sup>	.18 <sup>b</sup>
Vanillin, tins ....oz.	.43	.58	.39	.48	.48	.53	.48	.48
Vermilion, Eng., kegs, bbls. ....lb.	.82	1.35	1.20	1.35	1.20	1.45	1.35	1.55
Whiting, com., bulk ....cwt.	1.00	1.15	1.00	1.00	.85	1.15	1.00	1.15
Xylene, (xylol), nitration, drs., wks. ....gal.	.43	.45	.45	.65	.40	.55	.45	.70
Xylidine, crude, drs. ....lb.	.40	.42	.42	.47	.40	.47	.38	.40
Zinc chloride, fused, drs. ....lb.	.05	.07	.05	.06	.05	.05 1/2	.05 1/2	.06 1/2
Zinc oxide, Am., 5% PbSO., bags, c/l ....lb.	.06 1/4	.07 3/4	.06 1/4	.07 1/4	.07 3/8 <sup>c</sup>	.07 1/2 <sup>c</sup>	.07 1/4 <sup>c</sup>	.07 3/8 <sup>c</sup>
sulfate, bbls., wks. ....lb.	.02 3/4 <sup>a</sup>	.03 3/4 <sup>b</sup>	.03 3/4 <sup>a</sup>	.03 3/4 <sup>b</sup>	.03 1/4 <sup>a</sup>	.03 1/4 <sup>b</sup>	.03 1/4 <sup>a</sup>	.03 1/4 <sup>b</sup>

<sup>a</sup> June price; <sup>b</sup> Dec. price; <sup>c</sup> Bbls., N. Y.; <sup>d</sup> Per unit; <sup>e</sup> Lead-free.

# PRICE LIST OF IMPORTANT REPRESENTATIVE CHEMICALS AND RELATED PRODUCTS, 1922-29 (Continued)

	1926		1927		1928		1929	
	low	high <sup>b</sup>	low	high <sup>b</sup>	low	high <sup>b</sup>	low	high <sup>b</sup>
Sodium sulfide, 62% solid, drs., wks. ....lb.	.03 <sup>a</sup>	.03 <sup>3</sup> / <sub>4</sub> <sup>b</sup>	.03 <sup>1</sup> / <sub>4</sub> <sup>a</sup>	.03 <sup>1</sup> / <sub>2</sub> <sup>b</sup>	.03 <sup>1</sup> / <sub>2</sub> <sup>a</sup>	.03 <sup>1</sup> / <sub>2</sub> <sup>b</sup>	.03 <sup>1</sup> / <sub>2</sub> <sup>a</sup>	.03 <sup>b</sup>
sulfite, cryst., bbls. ....lb.	.02 <sup>1</sup> / <sub>4</sub>	.03 <sup>1</sup> / <sub>2</sub>	.02 <sup>1</sup> / <sub>4</sub>	.03	.03	.03	.03	.03
Strontium nitrate, bbls. ....lb.	.08 <sup>a</sup>	.08 <sup>b</sup>	.08	.08 <sup>3</sup> / <sub>4</sub>	.08 <sup>3</sup> / <sub>4</sub>	.09	.08 <sup>3</sup> / <sub>4</sub>	.09 <sup>1</sup> / <sub>4</sub>
Strychnine sulfate, U.S.P., cryst. powd. ....oz.	.42 <sup>a</sup>	.38 <sup>b</sup>	.38 <sup>a</sup>	.38 <sup>b</sup>	.38 <sup>a</sup>	.46 <sup>b</sup>	.46 <sup>a</sup>	.42 <sup>b</sup>
Sulfur, crude (brimstone), f.o.b. mines .....ton	17.00	19.00	18.00	18.00	18.00	18.00	18.00	18.00
chloride, red., drs., wks. ....lb.	.05 <sup>a</sup>	.05 <sup>b</sup>	.05	.05	.05	.05 <sup>1</sup> / <sub>2</sub>	.05	.05 <sup>1</sup> / <sub>2</sub>
dioxide, cys. ....lb.	.17 <sup>a</sup>	.17 <sup>b</sup>	.08	.08	.08	.08 <sup>1</sup> / <sub>2</sub>	.07	.08 <sup>1</sup> / <sub>2</sub>
Superphosphate, 16%, bulk, wks. ....ton	8.50	10.40	8.50	8.75	8.50	10.00	9.00	10.00
Tankage, conc., bulk, f.o.b. Chicago .....unit	3.00	3.50	3.50	4.00	3.75	4.25	3.90	4.25
Terpineol, C.P., drs. ....lb.	.30 <sup>a</sup>	.38 <sup>b</sup>	.36 <sup>a</sup>	.33 <sup>b</sup>	.33 <sup>a</sup>	.33 <sup>b</sup>	.33 <sup>a</sup>	.27 <sup>b</sup>
Thiocarbamide, bbls. ....lb.	.24 <sup>a</sup>	.22 <sup>b</sup>	.22	.22	.22	.24	.22	.24
Thymol, bottles .....lb.	2.75	4.25	2.60	2.95	2.25	2.75	2.00	2.25
Tin, cryst., bbls. ....lb.	.41 <sup>1</sup> / <sub>2</sub>	.48 <sup>1</sup> / <sub>2</sub>	.41	.48	.36	.42	.32 <sup>1</sup> / <sub>2</sub>	.37 <sup>1</sup> / <sub>2</sub>
tetrachloride, drs., wks. ....lb.	.35 <sup>1</sup> / <sub>2</sub> <sup>a</sup>	.40 <sup>b</sup>	.35 <sup>1</sup> / <sub>2</sub>	.48	.30 <sup>1</sup> / <sub>2</sub>	.35 <sup>1</sup> / <sub>2</sub>	.27 <sup>1</sup> / <sub>4</sub>	.30 <sup>1</sup> / <sub>4</sub>
Titanium dioxide, bbls. ....lb.	—	—	.40	.40	.40	.40	.22	.50
Toluene (toluol), tks., wks. ....gal.	.35	.35	.35	.35	.35	.40	.40	.40
Toluidine, mixed, drs., wks. ....lb.	.31 <sup>a</sup>	.31 <sup>b</sup>	.31	.31	.31	.32	.31	.32
o-Toluidine, drs. ....lb.	.23	.25	.25	.28	.25	.28	.25	.27
p-Toluidine, cks. ....lb.	.48	.55	.38	.48	.38	.40	.38	.38
Triacetin, drs., wks. ....lb.	.36 <sup>a</sup>	.36 <sup>b</sup>	.36	.36	.36	.39	.36	.32
Tricresyl phosphate, drs. ....lb.	.36	.50	.36	.36	.36	.50	.33	.45
Turpentine, gum spirits, bbls. ....gal.	.84 <sup>1</sup> / <sub>2</sub>	1.13 <sup>1</sup> / <sub>2</sub>	.50	.87 <sup>1</sup> / <sub>2</sub>	.52	.62 <sup>1</sup> / <sub>2</sub>	.51 <sup>1</sup> / <sub>4</sub>	.63 <sup>1</sup> / <sub>2</sub>
Urea, pure, cases .....lb.	.18 <sup>a</sup>	.18 <sup>b</sup>	.18	.18	.18	.20	.15	.30
Vanillin, tins .....lb.	7.20	7.52	6.75	7.20	6.25	6.75	6.25	6.25
Vermilion, Eng., kegs, bbls. ....lb.	1.40	1.60	1.55	1.95	1.75	2.00	1.85	1.90
Whiting, com., bulk .....cwt.	.85	1.00	.85	.85	.85	.85	.85	.85
Xylene, (xylol), nitration, drs., wks. ....gal.	.55	.70	.55	.55	.55	.50	.50	.50
Xylidine, crude, drs. ....lb.	.38	.40	.38	.38	.37	.37	.37	.37
Zinc chloride, fused, drs. ....lb.	.05 <sup>1</sup> / <sub>4</sub>	.06	.05 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>	.05 <sup>1</sup> / <sub>4</sub>
oxide, Am., lead-free, bags, c/1 .....lb.	.06 <sup>1</sup> / <sub>2</sub>	.07 <sup>1</sup> / <sub>4</sub>	.06 <sup>1</sup> / <sub>2</sub>	.06 <sup>1</sup> / <sub>2</sub>	.06 <sup>1</sup> / <sub>2</sub>	.06 <sup>1</sup> / <sub>2</sub>	.06 <sup>1</sup> / <sub>2</sub>	.06 <sup>1</sup> / <sub>2</sub>
sulfate, bbls., wks. ....lb.	.03 <sup>a</sup>	.03 <sup>b</sup>	.03	.03 <sup>1</sup> / <sub>2</sub>	.03 <sup>1</sup> / <sub>2</sub>	.03 <sup>1</sup> / <sub>2</sub>	.03	.03 <sup>1</sup> / <sub>4</sub>

<sup>a</sup> June price; <sup>b</sup> Dec. price.

## Appendix V

## U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29

(pounds)

(From Chemical Foundation & *O.P.D. Reprtr.*)

Starred (\*) items for fiscal years ending June 30th, remaining for calendar years; n.e.s. = not elsewhere specified; n.s.p.f. = not specially provided for. All data from official sources; where missing, not available.

Acenaphthene, fluorene, methylantracene, methylnaphthalene*			Acid, acetic (concentrated)		
1923.....	23,739	\$ 2,843	1923.....	664,034	\$ 79,553
1926.....	20,000	1,457	1924.....	1,202,765	144,003
1927.....	52,224	13,791	1925.....	2,059,185	232,950
1928.....	55,272	16,358	1926.....	1,995,982	232,855
1929.....	44,237	11,704	1927.....	3,784,504	454,382
			1928.....	5,363,658	647,208
			1929.....	7,824,521	727,847
Acetaldehyde			Acid, acetic (dilute)		
1923.....*	163,913	\$26,338	1923.....	37,052	\$ 4,758
1924.....	132,344	22,493	1924.....	371,732	27,080
1925.....	267,023	41,790	1925.....	362,214	29,130
1926.....	94,724	12,950	1926.....	6,026,859	289,282
1927.....	50	20	1927.....	6,766,512	350,421
1928.....	4,472	803	1928.....	12,163,499	644,816
1929.....	10,770	1,622	1929.....	21,410,253	1,283,002
Acetaldol, <i>see</i> Aldol			Acid, acetic anhydride*		
1923.....	20	\$ 32	1923.....	2,350	\$ 638
1924.....	38	50	1924.....	3,746	1,141
1925.....	13	26	1925.....	6,208	1,728
1926.....	95	175	1926.....	129,953	24,274
1927.....	974	2,501	1927.....	50,027	12,315
1928.....	981	1,451	1928.....	2,217	438
1929.....	500	700	1929.....	20,596	4,367
Acetanilide (medicinal), acetphenetidine, acetylsalicylic acid*			Acid, acetylsalicylic, <i>see</i> Acetanilide (medicinal)		
1923.....	20	\$ 32	1923.....	166,354	\$15,597
1924.....	38	50	1924.....	420	121
1925.....	13	26	1925.....	59,112	2,676
1926.....	95	175	1926.....	2,340	165
1927.....	974	2,501	1927.....	11,685	470
1928.....	981	1,451	1928.....	75	30
1929.....	500	700	1929.....	247	26
Acetanilide (nonmedicinal)*			Acid, arsenic		
1927.....	3,268	\$1,348	1923.....	166,354	\$15,597
Acetone			1924.....	420	121
1923.....	43,573	\$ 6,795	1925.....	59,112	2,676
1924.....	226,371	28,995	1926.....	2,340	165
1925.....	421,150	45,438	1927.....	11,685	470
1926.....	256,684	28,094	1928.....	75	30
1927.....	154,223	17,756	1929.....	247	26
1928.....	37,898	4,650	Acid, arsenious (white arsenic)		
1929.....	42,000	3,615	1923.....	20,304,545	\$1,985,400
Acetphenetidine (Phenacetin)*			1924.....	17,753,500	1,597,433
1924.....	25	\$ 238	1925.....	18,631,387	1,076,073
1925.....	300	1,020	1926.....	15,406,890	510,227
After 1925, <i>see</i> Acetanilide (medicinal)			1927.....	25,033,649	921,998

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Acid, arsenious (white arsenic) ( <i>Cont.</i> )			Acid, gallic*		
1928.....	22,305,972	\$775,169	1923.....	6,048	\$2,743
1929.....	26,314,042	956,176	Acid, glycerophosphoric, salts & compounds*		
Acid, benzoic (medicinal)*			1923.....	18,952	\$18,524
1923.....	200	\$775	1924.....	42,808	59,400
1924.....	111	168	1925.....	47,626	54,350
1925.....	431	279	1926.....	65,266	56,013
1926.....	230	200	1927.....	47,282	49,780
1927.....	261	157	1928.....	39,808	47,132
1928.....	300	181	1929.....	27,013	50,433
1929.....	319	195	Acid, hydrochloric		
Acid, boric			1923.....	954,709	\$ 9,036
1923.....	301,746	\$23,306	1924.....	104,312	915
1924.....	325,042	18,352	1925.....	1,320,115	10,166
1925.....	292,325	17,837	1926.....	1,180,295	7,451
1926.....	179,740	12,028	1927.....	100,000	858
1927.....	134,907	8,222	1928.....	1,404,850	8,334
1928.....	405,545	—	1929.....	83	45
1929.....	7,472	431	Acid, hydrofluoric*		
Acid, carbolic (phenol), <i>see</i> Phenol			1923.....	40	\$ 9
Acid, chromic			1924.....	157	32
1923.....	4,632	\$ 2,026	1926.....	10	8
1924.....	32,493	2,484	1928.....	61	70
1925.....	5,564	2,216	Acid, lactic*		
1926.....	7,220	2,892	1923.....	182,320	\$23,792
1927.....	15,620	9,755	Subdivided after 1923.		
1928.....	99,617	24,547	Acid, lactic, under 30%*		
1929.....	462,486	84,683	1925.....	12,255	\$4,354
Acid, cinnamic*			1926.....	31,847	3,958
1924.....	112	\$389	Acid, lactic, 30-55%*		
Not stated after 1925			1924.....	192,108	\$10,963
Acid, citric			1925.....	258,830	13,145
1923.....	757,864	\$233,665	1926.....	613,873	45,615
1924.....	673,114	186,512	1927.....	404,828	27,559
1925.....	288,574	79,634	1928.....	216,967	14,366
1926.....	284,897	77,525	1929.....	73,146	5,614
1927.....	71,291	18,515	Acid, lactic, 55% & over*		
1928.....	1,338	524	1924.....	58,897	\$12,375
Acid, diethylbarbituric & derivatives*			1925.....	118,946	36,065
1928.....	26,074	\$216,111	1926.....	77,534	24,956
1929.....	26,531	216,340	1927.....	234,399	76,391
Acid, formic			1928.....	237,538	71,984
1923.....	1,282,004	\$ 96,174	1929.....	295,393	87,808
1924.....	1,532,798	121,431	Acid, mixed*		
1925.....	1,487,149	105,155	1926.....	226,472	\$1,364
1926.....	2,315,308	164,045	1927.....	150	25
1927.....	3,214,642	230,565	Acid, nitric, <i>see</i> Appendix XX		
1928.....	2,260,090	174,246			
1929.....	1,386,608	108,797			

## Acid, oleic

1923.....	11,083	\$ 1,275
1924.....	36,796	4,214
1925.....	32,922	4,556
1926.....	30,833	5,085
1927.....	78,566	7,140
1928.....	46,282	5,900
1929.....	208,507	21,325

## Acid, oxalic

1923.....	2,621,302	\$206,100
1924.....	3,135,664	177,641
1925.....	2,568,275	117,639
1926.....	1,583,011	71,685
1927.....	1,843,732	98,657
1928.....	890,203	46,447
1929.....	1,346,053	71,193

Acid, phenylglycine-*o*-carboxylic\*

1924.....	17,376	\$74,492
Not stated after 1925.		

## Acid, phosphoric

1923.....	281,118	\$32,122
1924.....	42,201	5,895
1925.....	233,221	24,135
1926.....	228,550	24,800
1927.....	637,412	67,366
1928.....	316,470	32,665
1929.....	226,819	24,373

## Acid, phthalic\*

1923.....	2,205	\$619
Not stated after 1925.		

## Acid, pyrogallic\*

1923.....	232	\$393
1924.....	11	24
1925.....	11	21

## Acid, salicylic (medicinal), &amp; salts\*

1923.....	43	\$ 113
1924.....	4	55
1925.....	561	640
1926.....	137	3,343
1927.....	94	637
1928.....	201	1,377
1929.....	332	978

## Acid, salicylic (nonmedicinal), &amp; salts\*

1924.....	1,100	\$847
1925.....	1,757	521

Not stated after 1925.

## Acid, silicic\*

1923.....	100	\$17
Not stated after 1923.		

## Acid, stearic

1923.....	470,393	\$ 52,826
1924.....	266,472	31,608
1925.....	1,265,877	156,002
1926.....	1,769,861	223,331
1927.....	1,022,275	105,793
1928.....	2,003,042	226,268
1929.....	7,767,464	980,753

Acid, sulfuric (50° Bé.), *see* Appendix XI

## Acid, tannic, under 50%\*

1925.....	27,199	\$ 3,828
1926.....	87,907	14,830
1927.....	62,522	8,023
1928.....	46,610	7,148
1929.....	77,232	11,859

## Acid, tannic (medicinal), 50% &amp; over\*

1923.....	88	\$75
1924.....	3	10
1927.....	1,120	491
1928.....	75	91
1929.....	350	197

## Acid, tannic (nonmedicinal), 50% &amp; over\*

1925.....	41,284	\$10,661
1926.....	63,421	16,698
1927.....	122,857	33,601
1928.....	49,905	13,863
1929.....	33,024	9,559

## Acid, tartaric

1923.....	2,438,129	\$594,201
1924.....	2,997,233	626,266
1925.....	3,472,252	690,979
1926.....	1,575,016	331,374
1927.....	2,757,937	618,624
1928.....	1,810,362	575,484
1929.....	2,221,503	721,792

## Acid, valeric\*

1923.....	540	\$ 827
1925.....	222	352
1926.....	62,685	6,699
1927.....	725	1,057
1928.....	2,532	2,364
1929.....	2,031	2,876

## Acids &amp; anhydrides, n.s.p.f.\*

1923.....	1,306,932	\$ 92,725
1924.....	116,701	15,202
1925.....	96,839	21,639
1926.....	1,403,585	196,723
1927.....	858,567	131,375

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Acids & anhydrides, n.s.p.f.* ( <i>Cont.</i> )			Alizarin, natural*		
1928.....	505,668	\$103,485	1923.....	14,795	\$25,323
1929.....	367,462	108,871	1924.....	8,286	12,754
Alcohol, amyl*			1925.....	2,961	9,531
1924.....	26,508	\$12,377	1926.....	3,372	5,022
1925.....	53,075	17,505	1927.....	1,129	1,498
1926.....	5,354	2,105	1929.....	17,518	21,827
1927.....	4,307	1,173	Alizarin, synthetic*		
1928.....	8,176	2,627	1923.....	15,175	\$17,052
1929.....	7,175	2,292	1925.....	3,002	12,008
Alcohol, butyl			1927.....	1,406	711
1923.....	969,112	\$186,352	1928.....	25	48
1924.....	404,882	97,861	Alizarin colors & dyes*		
1925.....	2,152,092	392,770	1923.....	246,550	\$385,490
1926.....	205,317	33,237	1924.....	259,589	322,611
1927.....	31,751	5,569	1925.....	19,668	34,616
1928.....	39,903	7,957	1926.....	25,651	62,654
1929.....	5,045	1,127	1927.....	48,520	48,246
Alcohol, ethyl (pure grain)*			1928.....	5,410	5,560
1923.....	3	\$ 2	1929.....	102	163
1925.....	8	10	Alum, <i>see</i> Ammonia alum; Potash alum		
1927.....	120	648	Aluminum, crude, scrap & alloy*		
1928.....	190	855	1923.....	47,619,231	\$ 8,541,049
1929.....	4,663	11,835	1924.....	36,923,348	6,609,026
Proof gallons.			1925.....	26,191,182	5,998,045
Alcohol, ethyl (denatured)*			1926.....	66,470,355	15,430,256
1926.....	375	\$ 260	1927.....	67,666,489	15,072,461
1927.....	60,536	32,500	1928.....	51,787,740	10,848,665
1928.....	169,085	122,915	1929.....	43,250,854	5,485,421
1929.....	42,729	27,997	Aluminum hydroxide (refined bauxite)*		
Proof gallons.			1923.....	2,083,043	\$57,328
Alcohol, methyl			1924.....	672,629	35,655
1923.....	15,586	\$ 12,490	1925.....	543,093	40,847
1924.....	48	29	1926.....	445,584	29,246
1925.....	508,409	231,086	1927.....	210,065	17,304
1926.....	758,889	347,307	1928.....	241,584	16,086
1927.....	1,710,470	716,635	1929.....	509,414	24,372
1928.....	379,291	129,339	Aluminum salts & compounds, n.e.s.*		
1929.....	538,427	214,667	1925.....	27,297	\$ 9,426
Gallons.			1926.....	92,206	30,983
Alcohol, propyl*			1927.....	337,353	27,736
1925.....	32,433	\$11,692	1928.....	226,549	15,421
1926.....	8,623	2,954	1929.....	102,274	7,608
1927.....	40,079	9,157	Aluminum sulfate		
1928.....	14,397	2,920	1923.....	706,069	\$11,564
1929.....	26,686	5,659	1924.....	714,910	9,390
Aldol, or acetaldo!					
1927.....	220	\$44			
1928.....	70	15			

1925.....	1,712,598	\$18,751
1926.....	1,993,282	20,856
1927.....	1,532,766	19,436
1928.....	1,116,568	11,430
1929.....	2,525,172	25,556

## Aminonaphthol, -phenetole, &amp; -phenol\*

1923.....	32	\$4,355
1926.....	400	497

## Ammonia, anhydrous (liquid)\*

1923.....	107,844	\$4,203
1924.....	11,033	560
1925.....	176	26
1926.....	400	16
1929.....	56	12

## Ammonia aldehyde\*

1924.....	20	\$ 8
1925.....	2,094	796
1926.....	910	348
1927.....	253	78

## Ammonia alum

1923.....	185,906	\$4,379
1924.....	194,801	3,395
1925.....	238,195	4,917
1926.....	151,677	2,628
1927.....	193,500	3,683
1928.....	171,198	3,452
1929.....	96,931	2,186

## Ammonium carbonate &amp; bicarbonate

1923.....	807,330	\$47,766
1924.....	816,543	44,810
1925.....	643,185	41,761
1926.....	573,331	35,808
1927.....	786,361	48,684
1928.....	1,356,875	67,327
1929.....	860,834	42,970

## Ammonium chloride (sal ammoniac)\*

1923.....	3,240,055	\$174,996
1924.....	4,073,043	193,574

Stated separately after 1924.

## Ammonium chloride, gray\*

1925.....	2,230,667	\$100,919
1926.....	864,627	33,676
1927.....	2,039,798	79,360
1928.....	2,831,796	90,168
1929.....	5,886,654	178,487

## Ammonium chloride, white\*

1925.....	9,488,578	\$420,100
1926.....	10,014,027	403,078

1927.....	15,714,506	\$590,225
1928.....	8,056,984	269,114
1929.....	5,931,375	185,407

## Ammonium nitrate

1923.....	19,919,016	\$1,298,105
1924.....	3,747,531	209,399
1925.....	10,871,929	541,672
1926.....	8,353,106	383,405
1927.....	11,218,060	450,587
1928.....	13,172,099	525,744
1929.....	9,495,613	349,434

## Ammonium perchlorate\*

1923.....	496,683	\$23,635
1924.....	890,735	29,040
1925.....	106,501	7,233
1926.....	448	52
1927.....	23,467	1,942
1928.....	13,467	755
1929.....	1,144	145

## Ammonium phosphate\*

1923.....	409,182	\$38,556
1924.....	57,387	6,246
1925.....	100,480	9,922
1926.....	147,664	15,289
1927.....	491,111	23,812
1928.....	151,538	13,684
1929.....	76,621	4,770

## Ammonium sulfate

1923.....	3,542	\$ 204,616
1924.....	6,000	342,000
1925.....	23,762	1,325,743
1926.....	8,386	468,232
1927.....	17,153	780,323
1928.....	37,619	1,572,242
1929.....	18,812	762,516

Tons.

## Ammonium sulfate-nitrate\*

1927.....	12,203	\$ 815,276
1928.....	69,404	4,011,501
1929.....	63,273	3,545,219

Tons.

## Amyl acetate

1923.....	26,418	\$9,612
1925.....	20,534	7,160
1926.....	5,412	2,564
1927.....	300	150
1928.....	539	211
1929.....	300	82

## Anethole, citral, geraniol, heliotropin, terpineol, etc.\*

1928.....	211,749	\$62,071
1929.....	252,483	95,736



U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

<b>Aniline oil &amp; salts*</b>			<b>Antimony salts &amp; compounds, n.e.s.*</b>		
1923.....	85	\$ 231	1924.....	953,062	\$69,134
1926.....	500	130	1925.....	989,783	83,314
1927.....	1,440	1,404	1926.....	356,947	32,714
1928.....	35,260	23,147	1927.....	89,015	15,135
1929.....	6,980	5,794	1928.....	48,785	7,484
			1929.....	124,293	16,387
<b>Anthracene, under 30%*</b>			<b>Antimony sulfides, red &amp; golden*</b>		
1923.....	240,380	\$ 8,045	1924.....	147,241	\$26,872
1924.....	859,217	22,373	1925.....	248,060	29,215
1925.....	514,561	9,394	1926.....	1,027,463	69,452
1926.....	468,385	8,619	1927.....	907,136	62,968
1927.....	23,241	589	1928.....	721,457	61,528
1928.....	112,585	2,203	1929.....	472,852	42,704
1929.....	22,629	1,585			
<b>Anthracene, 30% &amp; over*</b>			<b>Antipyrine*</b>		
1923.....	2	\$ 2	1923.....	12,688	\$18,897
1926.....	323	126	1924.....	12,993	18,129
1929.....	1,052	405	1925.....	10,502	11,748
			1926.....	11,327	10,611
<b>Anthracene oil*</b>			1927.....	44,984	41,323
1923.....	26,845	\$5,401	1928.....	63,245	55,250
1924.....	22,995	5,670	1929.....	75,954	63,289
1925.....	17,343	2,842			
1926.....	14,538	2,140	<b>Argols (crude potassium bitartrate)</b>		
1927.....	9,623	1,044	1923.....	19,665,237	\$1,499,389
1928.....	18,004	4,107	1924.....	16,833,752	1,103,296
1929.....	39,399	8,689	1925.....	24,712,417	1,694,538
Gallons.			1926.....	25,570,201	1,791,160
			1927.....	24,901,551	2,288,968
<b>Anthracene &amp; carbazole colors, &amp; dyes therefrom*</b>			1928.....	12,890,368	1,330,368
1923.....	285,744	\$305,836	1929.....	17,686,005	2,077,763
1924.....	4,276	4,330			
1929.....	20	40	<b>Arsenic*</b>		
			1924.....	207,308	\$40,501
<b>Anthraquinone, aminoanthraquinone, nitroanthraquinone*</b>			1925.....	124,817	27,901
1926.....	6,625	\$ 7,914	1926.....	201,987	42,060
1927.....	6,808	5,705	1927.....	102,577	20,503
1928.....	15,483	12,935	1928.....	270,160	51,938
1929.....	22,492	15,543	1929.....	209,373	38,666
<b>Antimony oxide</b>			<b>Arsenic sulfide, realgar, &amp; orpiment*</b>		
1923.....	3,500,830	\$176,672	1923.....	4,817,824	\$429,959
1924.....	1,321,955	92,988	1924.....	474,571	51,300
1925.....	2,056,886	221,506	1925.....	458,092	50,180
1926.....	3,433,559	441,044	1926.....	938,908	55,108
1927.....	3,624,152	399,729	1927.....	485,990	35,610
1928.....	4,535,049	378,267	1928.....	434,984	38,930
1929.....	3,783,125	278,523	1929.....	498,639	50,396
			<b>Arsphenamine, see Salvarsan</b>		
			<b>Atropine &amp; salts, non-coal-tar*</b>		
			1924.....	400	\$840
			1925.....	225	452
			<b>Ounces; not stated after 1925.</b>		

Barium carbonate, crude, *see* Witherite

## Barium carbonate, precipitated

1923.....	3,801,449	\$ 79,482
1924.....	7,504,180	128,217
1925.....	14,376,333	160,164
1926.....	18,528,095	190,012
1927.....	9,836,188	119,014
1928.....	10,443,443	116,241
1929.....	6,412,446	69,236

## Barium chloride

1923.....	2,555,341	\$75,014
1924.....	4,660,650	100,810
1925.....	4,334,120	67,306
1926.....	3,546,758	49,426
1927.....	3,154,853	45,285
1928.....	2,344,904	25,253
1929.....	156,640	3,049

## • Barium dioxide\*

1923.....	2,140,050	\$188,574
1924.....	1,777,598	144,164
1925.....	1,580,154	91,768
1926.....	484,796	27,497
1927.....	14,407	1,445
1928.....	12,242	1,291
1929.....	409	49

## Barium hydroxide\*

1924.....	375,553	\$ 9,792
1925.....	239,368	5,611
1926.....	225,130	5,162
1927.....	561,209	13,237
1928.....	377,799	10,073
1929.....	426,231	11,946

## Barium nitrate

1923.....	1,022,729	\$59,766
1924.....	1,025,311	54,638
1925.....	1,405,957	58,192
1926.....	1,203,611	49,494
1927.....	1,421,053	65,284
1928.....	1,578,358	69,010
1929.....	1,229,916	56,770

## Barium sulfate, precipitated (blanc fixe)

1923.....	1,174,518	\$ 32,063
1924.....	2,093,665	50,465
1925.....	3,992,203	81,439
1926.....	5,946,454	136,697
1927.....	4,799,205	107,179
1928.....	7,359,664	168,923
1929.....	7,001,690	168,367

## Barytes, crude\*

1924.....	18,752	\$116,534
1925.....	22,473	119,879
1926.....	27,978	103,020
1927.....	60,535	277,729
1928.....	53,867	195,806
1929.....	78,121	280,586
Tons.		

## Barytes, ground\*

1924.....	4,235	\$65,388
1925.....	2,602	88,551
1926.....	2,667	38,920
1927.....	3,179	45,730
1928.....	2,763	32,478
1929.....	2,415	30,159
Tons.		

## Bauxite, crude

1923.....	119,020	\$ 593,882
1924.....	201,974	909,493
1925.....	353,696	1,549,120
1926.....	281,644	1,187,497
1927.....	356,580	1,572,236
1928.....	350,111	1,534,498
1929.....	380,812	1,753,840
Tons.		

Bauxite, refined, *see* Aluminum hydroxideBenzaldehyde (medicinal),  
*see*  $\beta$ -Naphthol

## Benzaldehyde (nonmedicinal) &amp; nitrobenzaldehyde\*

1925.....	2,204	\$1,212
1926.....	1,141	745
1927.....	3,769	4,089
1928.....	2,126	1,376
1929.....	2,248	1,462

## Benzanthrone, benzdine sulfate, etc.\*

1924.....	7	\$ 23
1926.....	5,269	3,585
1927.....	313,197	191,764
1928.....	215,356	132,736
1929.....	119,923	63,848

## Benzene

1923.....	701,857	\$ 21,902
1924.....	363,742	12,632
1925.....	1,573,250	44,313
1926.....	8,315,966	215,314
1927.....	2,991,729	63,962
1928.....	7,268,258	166,011
1929.....	18,164,952	405,029

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Benzidine, <i>see</i> Benzanthrone			1927.....	13,440,000	\$187,679
Benzyl chloride*			1928.....	6,000	213,635
1923..... 39 \$32			1929.....	4,165	136,307
Not stated after 1925.			In tons after 1927.		
Bismuth*			Borax, refined*		
1923..... 108,475 \$236,207			1923.....	62	\$ 15
1924..... 33,398 75,404			1924.....	169,516	7,005
1925..... 59,051 89,203			1925.....	1,323	248
1926..... 72,741 185,350			1926.....	1,120	175
1927..... 65,715 153,640			1927.....	20,014	1,627
1928..... 44,433 82,098			1928.....	208,659	4,586
1929..... 39,691 66,800			1929.....	5,215	1,018
Bismuth salts & compounds*			Bromine		
1924..... 10,652 \$14,518			1923.....	782	\$ 1,171
1925..... 692 1,522			1924.....	37,318	8,958
1926..... 14,188 17,275			1925.....	8,009	2,110
1927..... 11,441 16,467			1926.....	37,839	14,486
1928..... 9,716 14,373			1929.....	17,573	5,804
1929..... 3,803 16,541			Bromine compounds, n.e.s.*		
Blanc fixe, <i>see</i> Barium sulfate			1924.....	17,075	\$ 3,099
Bleaching powder			1925.....	148,508	55,176
1923..... 1,394,745 \$50,532			1926.....	76,077	29,168
1924..... 1,267,427 54,644			1927.....	551,466	170,560
1925..... 2,099,683 62,233			1928.....	186,872	50,700
1926..... 3,760,168 85,055			1929.....	2,214	1,535
1927..... 2,711,921 75,550			Browns: Spanish, Indian red, col- cothar, or iron oxide*		
1928..... 3,146,796 79,589			1923.....	20,273,852	\$724,244
1929..... 2,791,259 77,272			Not stated after 1923.		
Blues: Berlin, Prussian, Chinese, etc.*			Browns: Vandyke, Cassel earth or Cas- sel brown*		
1923..... 18,190 \$ 7,871			1923.....	478,281	\$12,882
1924..... 23,156 5,786			1924.....	418,605	7,877
1925..... 16,182 5,071			1925.....	486,407	9,364
1926..... 8,998 2,892			1926.....	988,962	17,424
1927..... 14,202 4,654			1927.....	1,508,459	22,735
1928..... 18,581 5,202			1928.....	1,113,270	19,864
1929..... 47,435 12,846			1929.....	1,344,812	23,500
Borates, crude*			Butyl acetate		
1923..... 10,317,008 \$226,584			1928.....	5,347,902	\$701,827
1924..... 10,120,816 149,984			1929.....	7,824,234	981,953
1925..... 5,284,243 86,367			Butyraldehyde*		
1926..... 6,932,164 97,324			1926.....	10,586	\$ 2,632
Included in "Borax, crude," after 1926.			1927.....	55,114	11,005
Borax, crude*			1928.....	68,037	14,688
1923..... 1,916,900 \$44,458			1929.....	27,945	5,519
1924..... 2,240,100 22,724			Cadmium*		
1925..... 4,480,000 64,496			1923.....	2,256	\$2,553
1926..... 2,240,023 32,145					

1924.....	1,102	\$ 743	1925.....	4,506,725	\$ 37,121
1925.....	5	6	1926.....	14,743,465	96,742
1928.....	74,748	39,554	1927.....	13,027,889	85,456
1929.....	342,804	246,292	1928.....	18,525,156	100,223
			1929.....	16,472,841	113,573
Caffeine*					
1923.....	5,890	\$11,361	Calcium citrate		
1924.....	100	234	1923.....	1,672,604	\$200,143
1925.....	752	1,680	1924.....	1,938,647	199,620
1927.....	1,500	2,713	1925.....	3,475,964	376,694
1928.....	3,654	5,312	1926.....	3,039,319	347,073
1929.....	7,379	7,774	1927.....	416,045	46,865
Caffeine salts & non-coal-tar derivatives*			Calcium cyanamide		
1923.....	—	\$951	1923.....	68,532	\$3,622,398
1924.....	150	209	1924.....	75,558	3,687,794
1925.....	61	117	1925.....	97,954	4,689,438
1926.....	300	710	1926.....	89,728	4,244,795
1928.....	228	227	1927.....	109,330	4,337,021
1929.....	312	274	1928.....	135,727	4,685,101
			1929.....	184,260	6,220,996
Calcium*			Long tons.		
1923.....	41	\$ 141	Calcium nitrate		
1924.....	4,301	2,132	1923.....	10,283	\$ 366,340
1925.....	1,325	724	1924.....	7,682	347,304
1929.....	2,691	3,176	1925.....	7,777	328,208
Calcium acetate			1926.....	12,103	534,536
1923.....	22	\$ 18	1927.....	18,390	845,342
1924.....	3,003,981	83,237	1928.....	23,315	1,012,265
1925.....	4,973,475	119,419	1929.....	31,684	1,256,589
1926.....	4,934,394	154,724	Long tons.		
1927.....	6,893,052	225,508	Calcium sulfate, <i>see</i> Satin white		
1928.....	9,005,809	316,416	Calcium tartrate, crude, <i>see</i> Argols		
1929.....	24,583,610	997,735	Calomel, <i>see</i> Mercurous chloride		
Calcium arsenate			Camphor, refined synthetic		
1924.....	3,172	\$278	1923.....	488,684	\$ 302,473
1925.....	1,074	135	1924.....	682,035	377,661
1926.....	1,057	284	1925.....	1,797,577	900,543
1927.....	3,807	717	1926.....	2,869,562	1,523,818
1928.....	1,323	233	1927.....	2,941,286	1,276,875
Calcium carbide			1928.....	2,291,984	821,652
1923.....	7,126	\$509,762	1929.....	2,774,980	972,135
1924.....	7,762	587,428	Carbazole, 65% & over		
1925.....	7,120	515,014	1925.....	2,073	\$828
1926.....	10,922	846,624	1926.....	2,157	324
1927.....	2,225	167,406	Carbon tetrachloride*		
1928.....	1,264	91,975	1923.....	22,039	\$603
1929.....	1,887	141,365	1924.....	1,429	130
Short tons.			1926.....	107	43
Calcium chloride			Celestite, <i>see</i> Strontium carbonate		
1923.....	6,464,602	\$48,527			
1924.....	7,991,230	54,542			

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Cerium fluoride*			1924.....	118,343	\$1,095,603
1924.....	11,600	\$ 921	1925.....	149,739	1,207,430
1925.....	36,650	1,173	1926.....	215,464	1,704,947
1927.....	39,683	2,469	1927.....	222,360	1,748,858
1928.....	100	26	1928.....	212,829	1,689,936
Cerium nitrate*			1929.....	317,630	2,666,488
1924.....	969	\$ 811	Tons.		
1925.....	4,636	4,892	Chromium chloride*		
1926.....	2,786	3,194	1924.....	6,571	\$ 968
1927.....	42	71	1926.....	25,325	1,651
1928.....	15	19	1929.....	3,748	485
1929.....	114	131	Chromium sulfate*		
Cerium salts, n.s.p.f.*			1924.....	2,524	\$ 372
1924.....	3,951	\$ 1,087	1926.....	220	158
1925.....	82,335	3,693	1927.....	40,960	3,112
1926.....	16,970	1,493	1929.....	110	33
1927.....	22,150	1,710	Cinchona alkaloids or salts, n.e.s.*		
1928.....	67,006	5,131	1923.....	3,405,084	\$1,106,520
1929.....	149,667	11,667	1924.....	125,141	57,347
Chloral hydrate*			1925.....	361,153	177,866
1923.....	7,489	\$3,005	1926.....	386,906	98,914
1925.....	3,096	3,150	1927.....	381,356	105,490
1926.....	2	2	1928.....	213,938	30,465
1928.....	888	337	1929.....	134,000	52,829
1929.....	562	292	Ounces.		
Chloroform*			Cinchona bark*		
1923.....	396	\$136	1923.....	3,443,491	\$1,110,142
1925.....	88	101	1924.....	2,421,915	691,842
1926.....	18	19	1925.....	2,538,989	774,252
1927.....	11	30	1926.....	4,203,292	1,198,580
1928.....	10	34	1927.....	2,217,951	605,872
1929.....	65	73	1928.....	1,765,967	486,136
Chrome & chromium metal*			1929.....	2,060,648	561,067
1923.....	3,032,761	\$271,770	Cinchonidine & salts*		
1924.....	157,351	28,823	1924.....	355,902	\$140,963
1925.....	9,475	4,005	1925.....	310,640	118,596
1926.....	2,240	1,529	1926.....	437,512	164,047
1928.....	45,194	5,387	1927.....	381,400	128,830
1929.....	47,669	5,242	1928.....	214,973	67,155
Chrome colors*			1929.....	265,600	73,280
1923.....	83,837	\$15,320	Ounces.		
1924.....	67,693	15,338	Cinchonine & salts*		
1925.....	102,408	24,936	1924.....	96,940	\$42,358
1926.....	177,696	42,157	1925.....	52,500	18,881
1927.....	235,094	49,853	1926.....	60,596	16,469
1928.....	159,919	36,764	1927.....	93,400	26,644
1929.....	191,225	40,529	1928.....	101,000	26,242
Chromite			1929.....	152,700	37,053
1923.....	129,693	\$1,123,120	Ounces.		

## Cobalt, metal\*

1923.....	264,933	\$ 555,295
1924.....	156,147	366,588
1925.....	133,257	286,123
1926.....	250,257	536,274
1927.....	477,617	1,072,879
1928.....	356,797	756,838
1929.....	690,398	1,411,354

## Cobalt, ore\*

1923.....	48,447	\$55,918
1924.....	35,701	40,042
1925.....	36,685	21,145
1926.....	30,672	74,349
1927.....	194,969	9,738
1928.....	75,777	12,558
1929.....	235,771	40,446

## Cobalt linoleate\*

1925.....	807	\$ 294
1926.....	4,989	1,854
1927.....	24	22

## Cobalt oxide

1923.....	258,574	\$511,903
1924.....	226,703	440,898
1925.....	287,265	546,292
1926.....	333,132	632,478
1927.....	369,747	703,608
1928.....	364,154	692,753
1929.....	475,928	884,873

## Cobalt salts &amp; compounds, n.e.s.\*

1924.....	706	\$ 697
1925.....	160	261
1926.....	412	969
1927.....	186	289
1928.....	153	178
1929.....	1,372	1,077

## Cobalt sulfate\*

1924.....	28,659	\$17,351
1926.....	28,880	17,228
1927.....	34,071	17,639
1928.....	68,180	38,749
1929.....	71,354	41,157

## Collodion &amp; pyroxylin solutions\*

1923.....	73,107	\$ 59,976
1924.....	122,279	108,278
1925.....	103,952	92,024
1926.....	92,136	73,798
1927.....	288,451	254,111
1928.....	340,997	247,983
1929.....	219,078	190,261

See also Pyroxylin.

Copper acetate & subacetate, see Verdigris

## Copper oxide

1923.....	118,983	\$21,530
1924.....	75,821	12,582
1925.....	54,985	9,159
1926.....	341,602	60,280
1927.....	267,994	46,227
1928.....	261,350	44,975
1929.....	252,767	45,610

## Copper sulfate (blue vitriol)

1923.....	10,162,549	\$517,524
1924.....	3,886,013	162,472
1925.....	1,805,095	92,930
1926.....	2,558,584	117,269
1927.....	1,978,726	88,748
1928.....	3,611,842	172,256
1929.....	5,388,743	272,859

## Copperas, see Ferrous sulfate

Corrosive sublimate, see Mercuric chloride

## Cream of tartar (potassium bitartrate)

1923.....	1,280,209	\$194,084
1924.....	1,531,226	165,421
1925.....	315,652	43,625
1926.....	247,109	30,904
1927.....	259,357	50,030
1928.....	136,843	26,824
1929.....	166,726	26,435

## Creosote, see Oil, creosote

## Cresylic acid

1923.....	685,009	\$526,463
1924.....	989,675	530,737
1925.....	964,698	543,046
1926.....	1,019,833	536,686
1927.....	1,128,590	615,650
1928.....	1,050,805	579,508
1929.....	17,856,765	952,110

## Gallons.

## Crotonaldehyde\*

1924.....	2,072	\$ 829
1925.....	9,102	3,539
1926.....	6,449	2,248
1927.....	38,948	8,672

## Cryolite (Kryolith)

1923.....	6,375	\$319,959
1924.....	6,320	320,670
1925.....	9,844	690,651
1926.....	7,599	557,598
1927.....	5,064	410,876
1928.....	6,906	529,176
1929.....	7,778	670,841

## Tons.

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Cumene & cymene*			1926.....	7,250,262	\$111,016
1925.....	499	\$135	1927.....	7,059,379	66,473
			1928.....	8,192,131	50,350
			1929.....	9,501,063	55,556
Cyanides*			Ethanol, <i>see</i> Alcohol, ethyl		
1924.....	1,027,078	\$ 71,438	Ethers, up to 10% alcohol, n.e.s.*		
1925.....	230,239	19,572	1923.....	7,125	\$ 4,220
1926.....	128,763	9,303	1924.....	10,683	5,457
1927.....	66,151	54,269	1925.....	46,694	21,175
1928.....	227,095	98,906	1926.....	77,693	41,112
1929.....	630,645	223,776	1927.....	2,717,789	410,897
Diethyl sulfate*			1928.....	3,929,410	584,389
1924.....	83	\$ 246	1929.....	89,370	33,730
1925.....	375	1,353	Ethers, over 10% alcohol, n.e.s.*		
1926.....	311	2,035	1923.....	50,867	\$ 6,055
1927.....	30,066	7,221	1924.....	1,247	1,505
1928.....	22,447	5,549	1925.....	7,192	14,331
1929.....	21,334	4,577	1926.....	1,060	1,132
Dihydroxynaphthalene & dianisidine*			1927.....	2	3
1926.....	1,000	\$ 540	1928.....	51	56
1927.....	55	142	1929.....	6,217	4,506
1928.....	10,750	6,683	Ethyl acetate		
1929.....	1,950	1,180	1923.....	27,202	\$11,664
Dimethyl sulfate*			1924.....	253	39
1928.....	4,410	\$944	1925.....	12,759	2,150
1929.....	723	131	1926.....	855	89
Dimethylaniline & benzylethylaniline*			1927.....	3,748	391
1923.....	1	\$ 2	1928.....	110	33
1927.....	2,383	2,219	1929.....	74	73
Diphenylamine*			Ethyl chloride*		
1924.....	1,131	\$ 218	1923.....	17,335	\$19,850
1925.....	23,587	8,158	1924.....	7,187	8,839
1926.....	400	1,315	1925.....	15,462	18,146
1927.....	32	104	1926.....	855	1,088
1928.....	12,250	13,342	1927.....	642	749
1929.....	4,900	5,736	1928.....	132	172
Dye extracts, nonalcoholic & nonme-			1929.....	381	206
dicinal*			Ethyl chlorocarbonate*		
1924.....	1,297,786	\$118,455	1929.....	8,072,564	\$1,029,615
1925.....	511,139	72,565	Ethyl ether		
1926.....	241,277	27,504	1923.....	103	\$ 75
1927.....	580,697	65,760	1924.....	73	109
1928.....	330,311	32,089	1925.....	23	43
1929.....	575,324	34,630	1927.....	22	12
Dyeing materials, crude, n.e.s.*			1929.....	2,262	320
1923.....	6,912,336	\$174,955	Ethylene chlorohydrin*		
1925.....	9,140,366	152,334	1927.....	882	\$412
			1929.....	11	7

Ethylene chlorohydrin, dichloride,			Ferrous sulfate (copperas)		
glycol, & oxide*					
1925.....	25,124	\$10,934	1923.....	1,635,172	\$13,653
1926.....	1,711	831	1924.....	1,118,420	7,502
Stated separately after 1926.			1925.....	337,000	3,317
Ethylene dibromide*			1926.....	503,802	7,780
1928 (Jan.-June)	132,205	\$39,134	1927.....	805,956	12,389
1929.....	244,015	70,453	1928.....	699,278	10,478
Ethylene glycol*			1929.....	650,094	10,161
1927.....	1,577	\$429	Ferrous sulfide*		
1928.....	12	3	1924.....	2,618	\$ 457
1929.....	91	17	1925.....	16,412	926
Eucalyptol*			1926.....	23,567	1,566
1924.....	3,960	\$403	1927.....	17,842	602
1925.....	120	123	1928.....	8,449	296
1926.....	899	331	1929.....	33,170	1,143
1927.....	884	534	Ferrovanadium*		
1928.....	1,003	769	1923.....	1,160	\$ 3,770
1929.....	100	77	1927.....	1,058	328
Ferric chloride			1929.....	341,592	304,937
1923.....	64,097	\$ 3,184	Fertilizers, n.s.p.f.*		
1924.....	137,211	7,769	1923.....	117,426	\$3,646,490
1925.....	102,089	3,158	1924.....	110,943	2,338,149
1926.....	1,247,624	19,697	1925.....	37,429	684,617
1927.....	631,188	17,853	1926.....	154,766	3,154,204
1928.....	828,568	22,707	1927.....	85,607	1,589,167
1929.....	842,458	22,953	1928.....	76,484	1,688,224
Ferromanganese*			1929.....	860	55,648
1923.....	118,435	\$8,770,834	Tons.		
1924.....	56,776	4,605,681	Fertilizers, nitrogen, phosphoric acid,		
1925.....	68,405	5,902,225	& potash compounds*		
1926.....	48,197	4,766,798	1929.....	5,312	\$390,152
1927.....	33,704	2,229,878	Tons.		
1928.....	49,731	4,780,739	Flavors, coal-tar*		
1929.....	52,950	5,625,825	1924.....	11	\$ 13
Tons.			1926.....	2	33
Ferrophosphorus*			1928.....	715	881
1925.....	4,760	\$ 460	1929.....	165	413
1926.....	99,207	3,377	Fluorspar*		
1927.....	4,341,132	143,937	1923.....	14,454	\$378,443
1928.....	3,782,027	126,055	1924.....	47,366	567,109
1929.....	1,544,268	56,639	1925.....	49,175	570,641
Ferosilicon*			1926.....	44,413	487,600
1923.....	18,511	\$1,232,251	1927.....	70,607	698,406
1924.....	25,865,275	1,171,755	1928.....	44,716	442,901
1925.....	11,186,238	451,944	1929.....	43,033	430,594
1926.....	15,818,765	807,329	Tons.		
1927.....	29,143,719	1,428,030	Fluorspar, up to 93% CaF <sub>2</sub> *		
1928.....	9,055,982	506,297	1929.....	6,942	\$63,564
1929.....	15,583,086	1,067,259	Tons.		
In tons prior to 1924.					



U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Formaldehyde			1928.....	4,238,103	\$450,535
1923.....	166	\$ 67	1929.....	5,493,471	500,730
1925.....	9	16	Glycol, monoacetate*		
1926.....	396	431	1927.....	2,796	\$2,638
1927.....	1,347	89	1928.....	76,801	8,249
1928.....	4,188	194	1929.....	9,860	922
Fusel oil			Guaiacol & derivatives*		
1923.....	3,132,000	\$1,018,351	1923.....	5,906	\$12,865
1924.....	887,074	334,590	1924.....	2,285	5,678
1925.....	267,520	73,732	1925.....	6,087	9,247
1926.....	385,287	54,361	1926.....	2,193	4,683
1927.....	356,386	54,213	1927.....	43,229	37,303
1928.....	63,436	9,758	1928.....	5,055	6,879
1929.....	37,627	6,701	1929.....	10,570	13,211
Glauber's salt, <i>see</i> Sodium sulfate, crystalline			Gum, rosin, <i>see</i> Rosin		
Glazes, fluxes, enamels, & colors (ceramic & glass)*			Hexamethylenetetramine		
1923.....	150,703	\$102,213	1923.....	47,373	\$24,722
1924.....	164,568	107,248	1924.....	3,826	3,998
Subdivided after 1924.			1925.....	20,771	10,453
Glazes, fluxes, enamels, & colors (ceramic & glass), ground*			1926.....	23,481	10,237
1925.....	307,150	\$107,862	1927.....	3,417	1,715
1926.....	506,743	185,493	1928.....	5,898	1,643
1927.....	345,323	104,305	1929.....	5,562	1,857
1928.....	392,980	105,084	Hydrogen peroxide		
1929.....	572,862	176,837	1926.....	581,760	\$122,542
Glazes, fluxes, enamels, & colors (ceramic & glass), other*			1927.....	371,855	71,154
1925.....	106,125	\$ 42,515	1928.....	19,593	4,242
1926.....	627,991	208,444	1929.....	145,403	19,987
1927.....	558,794	165,742	Indigo, synthetic*		
1928.....	407,979	100,986	1923.....	27,750	\$35,200
1929.....	220,053	46,701	1924.....	356	117
Glycerin, crude			1925.....	2,116	948
1923.....	14,199,561	\$1,382,249	1926.....	1,589	280
1924.....	13,658,891	1,413,593	1927.....	590	610
1925.....	18,624,250	2,161,413	Indigo colors, dyes, stains, etc.*		
1926.....	27,729,343	3,849,222	1924.....	4,988	\$ 6,228
1927.....	13,666,006	2,026,175	1925.....	4,777	4,296
1928.....	4,009,248	290,723	1926.....	14,423	22,599
1929.....	14,851,901	863,552	1927.....	8,220	9,786
Glycerin, refined			1929.....	62	228
1923.....	585,792	\$ 76,994	Iodine, crude		
1924.....	1,500,644	229,897	1923.....	273,338	\$ 887,361
1925.....	2,043,606	305,796	1925.....	246,474	889,860
1926.....	10,839,093	2,328,936	1926.....	711,291	2,272,343
1927.....	8,288,574	1,697,330	1927.....	926,492	2,900,574
			1928.....	720,766	2,429,076
			1929.....	627,162	2,249,266
			Iron chloride, <i>see</i> Ferric chloride		

Iron hydroxide & oxide, <i>see</i> Pigments			1928.....	119,706	\$ 9,177
			1929.....	248,996	19,799
Iron sulfate, <i>see</i> Ferrous sulfate			Lead arsenate*		
Iron sulfide, <i>see</i> Ferrous sulfide			1924.....	3,611	\$ 534
Kainite*			1925.....	310	26
1923.....	173,353	\$1,133,576	1926.....	10,157	1,488
1924.....	181,287	1,080,132	1929.....	200	26
1925.....	144,642	865,201	Lead carbonate, basic, <i>see</i> White lead		
1926.....	190,955	1,252,942	Lead compounds, n.e.s.*		
1927.....	147,203	1,058,858	1923.....	14,013	\$1,951
1928.....	107,835	881,688	1924.....	26,978	3,412
1929.....	82,802	680,667	1925.....	25,489	2,826
Tons.			1926.....	19,907	2,998
Kieserite*			1927.....	70,274	9,812
1924.....	3,369,034	\$12,387	1928.....	12,907	1,932
1925.....	1,336,679	4,562	1929.....	45,704	7,641
1926.....	201,027	1,039	Lead nitrate*		
1927.....	1,000,945	4,610	1923.....	89,073	\$4,614
1928.....	50,000	362	1924.....	11,334	914
Lakes, coal-tar*			1925.....	28,532	2,440
1926.....	800	\$811	1926.....	41,489	3,481
1927.....	500	835	1927.....	92,220	9,607
1928.....	155	169	1928.....	52,101	4,828
Lakes, dry or pulp, n.s.p.f.*			1929.....	64,353	4,694
1923.....	6,091	\$7,322	Lead pigments, n.e.s.*		
1924.....	3,016	2,833	1923.....	14,050	\$1,099
1925.....	263	760	1924.....	27,615	3,883
Not stated after 1925.			1925.....	1,458	312
Lampblack*			1926.....	23,719	3,460
1924.....	751,396	\$59,436	1927.....	30,526	2,155
1925.....	836,629	54,984	1928.....	32,025	2,449
1926.....	1,120,160	74,627	1929.....	51,176	3,469
1927.....	412,304	28,796	Lead resinate*		
1928.....	486,296	32,450	1925.....	220	\$ 25
1929.....	381,974	21,922	1927.....	840	192
Lead acetate, brown, gray, or yellow*			1928.....	1,323	303
1923.....	11,023	\$ 768	Lead sulfate*		
1924.....	44,299	3,456	1926.....	266	\$ 30
1925.....	11,038	896	1927.....	11,000	563
1926.....	11,365	863	Lime, n.e.s.*		
1927.....	16,928	1,340	1923.....	266,747	\$352,651
1928.....	10,007	821	1924.....	488,845	411,550
1929.....	17,928	1,513	1925.....	25,128,561	249,369
Lead acetate, white*			1926.....	27,206,642	264,408
1923.....	70,297	\$ 5,010	1927.....	29,258,180	283,439
1924.....	153,307	12,798	1928.....	24,636,817	230,922
1925.....	163,142	15,995	1929.....	29,146,677	301,218
1926.....	163,707	14,983	Stated in cwt. prior to 1925; including hydrated lime prior to 1924.		
1927.....	303,687	29,390			

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Lime, chlorinated, <i>see</i> Bleaching powder			1928.....	15,440,005	\$193,101
			1929.....	11,810,039	140,914
			In tons prior to 1924.		
Lime, hydrated*			Magnesite, crude*		
1924.....	6,115,000	\$ 56,712	1923.....	35,427	\$430,568
1925.....	3,535,460	29,189	1924.....	2,890,394	11,237
1926.....	5,918,324	48,595	1925.....	23,795	559
1927.....	9,910,581	80,272	1926.....	963,489	5,946
1928.....	9,889,118	78,031	1927.....	1,365,618	8,255
1929.....	14,248,137	109,824	1928.....	1,968,266	9,160
Lime citrate*			1929.....	1,124,658	4,220
1923.....	7,572,925	\$1,103,584	In tons prior to 1924.		
1924.....	2,951,386	328,648	Magnesite, dead-burned*		
1925.....	1,984,741	211,289	1924.....	98,118,821	\$809,760
1926.....	3,469,202	395,777	1925.....	109,364,993	785,136
1927.....	1,755,948	190,202	1926.....	122,878,186	897,838
1928.....	194,528	21,773	1927.....	109,854,340	807,472
1929.....	3,138,451	78,208	1928.....	96,606,570	700,850
Litharge*			1929.....	87,314,051	639,781
1923.....	21,405	\$1,250	Magnesium, metal & scrap*		
1924.....	1,220	74	1923.....	135,622	\$37,591
1925.....	4,040	496	1924.....	7,608	3,586
1926.....	232	30	1925.....	1,501	785
1927.....	402	54	1926.....	2,277	807
1928.....	880	87	1927.....	7,385	2,105
1929.....	2,250	163	1929.....	1,000	1,048
Lithopone			Magnesium, powder*		
1923.....	20,879,258	\$776,383	1927.....	4,600	\$5,207
1924.....	13,660,135	543,025	1928.....	9,110	8,282
1925.....	12,659,841	478,395	1929.....	3,699	4,237
1926.....	17,371,468	661,700	Magnesium carbonate, precipitated*		
1927.....	15,957,900	656,166	1923.....	215,815	\$13,285
1928.....	19,770,703	808,200	1924.....	1,108,429	57,630
1929.....	16,818,000	725,554	1925.....	303,367	16,856
London purple, <i>see</i> Paris green			1926.....	236,655	15,953
Magnesia, calcined or oxide*			1927.....	263,988	17,131
1923.....	144,597	\$24,857	1928.....	306,474	17,415
1924.....	113,487	34,054	1929.....	411,625	23,781
1925.....	135,827	34,715	Magnesium chloride, anhydrous*		
1926.....	505,754	44,838	1923.....	19,270,756	\$196,085
1927.....	218,935	50,725	1924.....	56,692	2,738
1928.....	259,765	48,270	1925.....	135,500	1,785
1929.....	367,634	72,842	1928.....	44,374	315
Magnesite, caustic, calcined*			1929.....	427,114	3,125
1923.....	28,556	\$631,598	Magnesium chloride, n.e.s.*		
1924.....	28,761,792	366,645	1924.....	20,818,688	\$117,223
1925.....	31,029,564	367,195	1925.....	14,348,685	88,205
1926.....	32,482,377	371,218	1926.....	14,333,772	97,930
1927.....	25,772,216	280,153	1927.....	13,614,086	95,302

1928.....	6,997,796	\$51,156
1929.....	3,957,214	28,024

## Magnesium silicofluoride\*

1927.....	775,736	\$45,416
1928.....	549,536	23,452
1929.....	217,916	12,890

## Magnesium sulfate (Epsom salt)

1923.....	14,455,920	\$71,566
1924.....	8,881,181	57,579
1925.....	8,211,228	50,466
1926.....	10,600,582	61,018
1927.....	11,620,675	60,527
1928.....	10,459,596	61,600
1929.....	13,541,189	82,416

## Manganese borate\*

1924.....	17,540	\$1,911
1925.....	10,164	713
1926.....	24,166	1,731
1927.....	11,720	1,076
1928.....	9,679	832
1929.....	15,698	995

## Manganese compounds &amp; salts, n.e.s.\*

1924.....	288,513	\$24,271
1925.....	140,430	6,613
1926.....	299,743	17,315
1927.....	286,770	16,157
1928.....	199,820	11,489
1929.....	292,487	13,146

## Manganese linoleate\*

1929.....	2,204	\$273
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## Manganese resinate\*

1924.....	66,490	\$4,980
1925.....	45,306	3,744

## Manganese sulfate\*

1924.....	85,293	\$4,344
1925.....	97,595	4,733
1926.....	57,729	3,080
1927.....	26,982	1,675
1928.....	24,713	1,433
1929.....	27,636	1,994

## Manure salts, double manure salts &amp; hard salts\*

1923.....	234,026	\$2,150,254
1924.....	244,994	2,687,062
1925.....	300,547	2,858,124
1926.....	372,124	3,716,362
1927.....	256,053	2,708,938
1928.....	375,801	5,021,710
1929.....	394,840	5,123,224

Tons.

## Menthol

1923.....	197,476	\$1,467,130
1924.....	194,641	1,735,273
1925.....	290,442	2,568,868
1926.....	451,681	2,808,205
1927.....	360,614	1,310,130
1928.....	242,564	873,808
1929.....	288,776	1,208,492

## Mercuric chloride (corrosive sublimate)

1923.....	790	\$ 605
1924.....	3,524	1,684
1925.....	1,463	919
1926.....	2,018	1,702
1927.....	5,044	6,405

## Mercurous chloride (calomel)\*

1923.....	2,847	\$3,259
1924.....	3,386	3,018
1925.....	4,796	4,093
1926.....	7,659	7,727
1927.....	5,526	6,458
1928.....	6,365	8,963
1929.....	2,623	4,137

## Mercury

1923.....	1,335,449	\$ 816,043
1924.....	987,719	566,820
1925.....	1,564,112	1,200,878
1926.....	1,948,170	1,784,250
1927.....	1,515,535	1,780,134
1928.....	1,106,736	1,437,153
1929.....	1,133,721	1,513,197

## Mercury oxide (red precipitate)\*

1924.....	8,728	\$ 6,672
1925.....	11,752	9,881
1926.....	36,500	34,151
1927.....	23,520	23,850
1928.....	6,148	7,189

## Mercury preparations, n.e.s.\*

1924.....	14,460	\$12,201
1925.....	24,262	19,887
1926.....	8,378	7,043
1927.....	12,301	13,440
1928.....	20,076	24,430
1929.....	5,358	8,941

Methyl alcohol, *see* Alcohol, methyl

## Methylantraquinone\*

1927.....	4,989	\$1,147
1929.....	3,628	3,344

Mineral earth, *see* Pigments

## U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (Cont.)

Mineral salts, from mineral waters*			1928.....	2,003	\$2,373
1923.....	37,863	\$18,685	1929.....	700	820
1924.....	26,459	28,735	Nickel oxide*		
1925.....	26,890	24,019	1923.....	2,966,259	\$322,536
1926.....	438,125	25,095	1924.....	1,407,931	176,086
1927.....	111,108	22,639	1925.....	796,071	121,107
1928.....	527,697	35,191	1926.....	1,777,799	247,353
1929.....	32,605	27,660	1927.....	1,264,188	220,447
Musk, artificial*			1928.....	961,776	140,497
1925.....	69,597	\$235,723	1929.....	2,516,127	381,763
1926.....	149,080	378,568	Niter cake, <i>see</i> Sodium bisulfate		
1927.....	132,375	341,991	<i>m</i> - & <i>p</i> -Nitroaniline*		
1928.....	148,426	455,341	1925.....	500	\$ 575
1929.....	118,904	400,127	1926.....	29,300	9,617
Naphthalene, solidifying under 79° C.*			1927.....	7,560	3,438
1923.....	12,153,047	\$287,836	1928.....	203,872	80,904
1924.....	14,020,568	397,386	1929.....	29,850	12,474
1925.....	2,044,728	34,256	Novocaine (procaine)*		
1926.....	5,354,458	97,232	1924.....	5	\$ 210
1927.....	6,419,923	118,597	1926.....	5	610
1928.....	15,529,243	205,378	1927.....	3	1,020
1929.....	32,417,444	575,710	1928.....	12	4,842
Naphthalene, solidifying at 79° C. or above*			1929.....	8	4,891
1923.....	32,374	\$2,928	Ochers, crude*		
1924.....	14,134	1,326	1923.....	7,284,183	\$113,928
1925.....	20	15	1924.....	105,087	1,913
1927.....	424	125	1925.....	235,090	3,448
1928.....	18,695	3,083	1926.....	235,622	4,470
$\alpha$ - & $\beta$ -Naphthol (nonmedicinal)*			1927.....	199,295	3,908
1923.....	10,050	\$ 22,120	1928.....	426,174	17,920
1924.....	14,352	31,771	1929.....	897,581	22,152
1925.....	2,310	975	Oil, China wood, China nut, or tung*		
1926.....	12,955	19,155	1923.....	11,918,985	\$10,188,994
1927.....	28,191	35,176	1924.....	10,786,453	13,847,626
1928.....	47,290	98,183	1925.....	94,696,963	10,957,533
1929.....	37,267	108,585	1926.....	84,860,373	9,118,828
$\beta$ -Naphthol & benzaldehyde (medicinal)*			1927.....	102,428,461	12,318,928
1923.....	2,770	\$4,022	1928.....	83,628,168	10,720,716
1924.....	801	1,202	1929.....	115,340,121	14,396,136
1925.....	2,806	3,036	In gallons prior to 1925.		
1926.....	1,736	2,672	Oil, creosote*		
1927.....	870	1,103	1923.....	52,565,292	\$ 6,850,489
1928.....	11	127	1924.....	81,353,086	13,522,540
1929.....	2	5	1925.....	88,416,560	11,435,278
Naphthylamine & naphthylenediamine*			1926.....	84,845,630	10,927,967
1927.....	250	\$255	1927.....	89,256,536	13,252,721
Gallons.			1928.....	92,371,381	14,475,542
			1929.....	81,814,098	11,172,264

Oil, fusel, *see* Fusel oil

## Opium, crude

1923.....	115,326	\$ 450,543
1924.....	64,041	600,174
1925.....	96,848	716,932
1926.....	144,011	951,573
1927.....	144,985	1,044,237
1928.....	102,986	648,316
1929.....	168,084	1,070,615

## Orange mineral\*

1923.....	134,105	\$10,680
1924.....	86,677	6,587
1925.....	83,709	8,109
1926.....	40,143	4,037
1927.....	68,967	5,536
1928.....	33,866	2,434
1929.....	69,489	5,816

## \* Palladium\*

1923.....	12,339	\$697,854
1924.....	12,918	768,514
1925.....	8,161	487,445
1926.....	8,412	495,897
1927.....	5,691	309,252
1928.....	11,382	373,815
1929.....	17,839	445,114

## Troy ounces.

## Paracetaldehyde

1923.....	363,752	\$ 63,593
1924.....	680,870	120,346
1925.....	808,049	124,363
1926.....	60,645	10,859
1927.....	21,258	4,017
1928.....	19,587	3,216
1929.....	42,853	8,369

## Paraformaldehyde\*

1925.....	34,816	\$ 5,920
1926.....	5	10
1927.....	500	141
1928.....	34,368	8,050
1929.....	45,136	10,730

## Paris green &amp; London purple\*

1923.....	102,429	\$20,912
1924.....	74,577	15,268
1925.....	2,595	771
1926.....	7,230	1,478
1927.....	22	6
1928.....	5,457	245
1929.....	7,822	1,252

Paris white, *see* Whiting

## Phenol

1923.....	126,618	\$21,389
1924.....	176,081	46,786
1925.....	256,126	58,958
1926.....	218,437	47,351
1927.....	500	100
1928.....	1,653	298
1929.....	433,385	44,226

## Phenolphthalein\*

1923.....	3,148	\$17,917
1924.....	1,270	1,791
1925.....	970	3,861
1926.....	1,488	1,910
1927.....	496	645
1928.....	2,614	2,292
1929.....	2,425	2,529

## Phenylenediamine, phenylglycine, etc.\*

1923.....	6	\$ 16
1926.....	2,475	2,559
1927.....	15,258	17,318
1928.....	750	894
1929.....	305	857

## Phosphate materials, crude, n.e.s.\*

1923.....	10,729	\$153,410
1924.....	1,714	36,274
1925.....	6,154	129,469
1926.....	4,165	81,437
1927.....	10,389	158,423
1928.....	17,265	174,047
1929.....	40	1,221

## Tons.

Phosphate rock, *see* Appendix XXII

## Phosphorus

1923.....	203,185	\$42,132
1924.....	104,467	37,024
1925.....	155,152	58,860
1926.....	126,305	48,667
1927.....	137,092	47,837
1928.....	106,345	34,831
1929.....	70,229	20,204

## Photographic chemicals, coal-tar\*

1923.....	17,371	\$29,470
1924.....	5,211	16,475
1925.....	6,958	21,728
1926.....	12,343	38,302
1927.....	26,796	68,101
1928.....	24,810	66,642
1929.....	19,997	61,237

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Pigments, black (excluding mineral earth), n.e.s.*			Potassium*		
1925.....	465,157	\$ 8,094	1923.....	4,013	\$740
1926.....	1,118,396	22,174	1924.....	103	52
1927.....	1,292,904	36,274	1929.....	61	603
1928.....	1,253,570	43,034	Potassium-antimony tartrate, <i>see</i> Tar-tar emetic		
1929.....	1,059,424	33,562	Potassium bicarbonate*		
Pigments, iron hydroxide & oxide*			1923.....	703,325	\$38,396
1924.....	22,908,117	\$584,353	1924.....	253,524	17,297
1925.....	26,516,612	624,259	1925.....	387,064	25,353
1926.....	26,281,730	658,101	1926.....	327,759	20,491
1927.....	26,348,690	638,511	1927.....	633,868	36,075
1928.....	25,070,870	586,004	1928.....	393,859	22,020
1929.....	24,392,199	578,656	1929.....	507,201	26,803
Pigments, mineral earth, n.e.s.*			Potassium bitartrate, <i>see</i> Argols; Cream of tartar		
1925.....	252,713	\$9,673	Potassium bromide		
1926.....	172,826	5,296	1923.....	52,833	\$ 5,736
1927.....	257,383	3,998	1924.....	935,749	124,414
1928.....	32,013	1,580	1925.....	237,231	62,082
1929.....	6,904	1,743	1926.....	70,440	18,549
Plumbago or graphite, amorphous*			1927.....	20,813	7,075
1924.....	26,053,208	\$152,320	1928.....	23,231	7,918
1925.....	16,860,716	119,844	1929.....	28,310	9,834
1926.....	16,931,791	147,093	Potassium carbonate		
1927.....	18,860,269	157,663	1923.....	9,812,667	\$ 518,632
1928.....	16,458,940	131,592	1924.....	7,137,531	290,396
1929.....	19,425,682	137,663	1925.....	9,926,062	349,286
Plumbago or graphite, crystalline flake*			1926.....	11,523,391	533,840
1924.....	3,123,636	\$ 79,678	1927.....	13,192,395	619,430
1925.....	2,817,127	76,783	1928.....	16,912,312	768,829
1926.....	7,222,180	427,866	1929.....	26,644,034	1,024,106
1927.....	3,805,559	208,201	Potassium chlorate & perchlorate*		
1928.....	3,480,611	180,224	1923.....	9,040,975	\$439,730
1929.....	7,510,847	314,694	1924.....	10,119,771	421,465
Plumbago or graphite, crystalline lump*			1925.....	9,834,711	406,554
1924.....	11,951,651	\$326,782	1926.....	6,242,161	245,723
1925.....	9,023,207	237,920	Stated separately after 1926.		
1926.....	12,891,839	503,539	Potassium chlorate		
1927.....	10,750,977	376,367	1926.....	12,110,875	\$430,883
1928.....	12,599,902	383,259	1927.....	13,122,384	476,887
1929.....	16,116,899	513,664	1928.....	11,980,027	425,462
Potash alum			1929.....	13,033,403	440,523
1923.....	2,356,814	\$49,271	Potassium chloride (muriate), crude		
1924.....	3,182,185	58,331	1923.....	135,497	\$4,116,180
1925.....	3,793,160	65,953	1924.....	129,128	3,982,288
1926.....	3,346,042	57,033	1925.....	161,028	5,193,866
1927.....	1,580,034	56,511	1926.....	199,151	6,195,830
1928.....	898,685	17,156	1927.....	163,817	5,739,097
1929.....	742,477	21,604			

1928.....	233,611	\$8,181,703	Potassium nitrate, crude		
1929.....	230,966	8,224,661	1923.....	2,747	\$137,228
Tons.			1924.....	689	54,628
Potassium chromate & bichromate*			1925.....	8,396	447,717
1923.....	8,301	\$1,710	1926.....	9,416	526,573
1924.....	8,862	1,631	1927.....	4,309	228,029
1925.....	7,950	1,402	1928.....	11,796	490,874
1926.....	6,107	1,092	1929.....	12,800	545,576
1927.....	7,756	1,321	Long tons.		
1928.....	4,708	853	Potassium nitrate, refined		
1929.....	8,598	1,482	1923.....	5,924,564	\$634,921
Potassium cyanide			1924.....	4,558,953	209,805
1923.....	1,966,337	\$116,835	1925.....	9,361,234	484,660
1924.....	2,822,996	232,971	1926.....	10,145,305	460,619
1925.....	2,298,964	216,683	1927.....	8,429,036	347,290
1926.....	103,555	36,350	1928.....	10,610,824	416,052
1927.....	340,198	70,077	1929.....	18,072,870	687,130
1928.....	115,583	43,590	Potassium perchlorate		
1929.....	137,343	54,204	1926.....	425,802	\$28,701
Potassium ferricyanide (red prussiate)*			1927.....	269,219	18,854
1923.....	114,142	\$75,850	1928.....	600,334	43,756
1924.....	71,585	29,705	1929.....	581,669	44,053
1925.....	115,666	32,498	Potassium permanganate*		
1926.....	108,015	30,390	1923.....	922,791	\$116,996
1927.....	167,533	46,444	1924.....	536,001	63,225
1928.....	100,532	28,545	1925.....	164,313	13,964
1929.....	123,519	32,854	1926.....	42,558	4,068
Potassium ferrocyanide (yellow prussiate)*			1927.....	347,799	29,669
1923.....	603,272	\$150,122	1928.....	416,008	36,032
1924.....	331,335	52,237	1929.....	351,085	32,486
1925.....	238,643	31,337	Potassium salts, n.e.s.*		
1926.....	182,685	20,875	1924.....	89,666	\$ 4,521
1927.....	167,589	22,208	1925.....	59,406	4,345
1928.....	125,948	16,178	1926.....	88,077	9,923
1929.....	150,068	19,359	1927.....	201,436	29,306
Potassium hydroxide (caustic)			1928.....	242,258	36,797
1923.....	10,837,197	\$ 685,309	1929.....	273,564	30,441
1924.....	12,629,379	698,635	Potassium-sodium tartrate (Rochelle salt)*		
1925.....	12,276,262	734,967	1923.....	327,778	\$48,918
1926.....	12,966,796	770,468	1924.....	305,064	37,507
1927.....	14,759,060	915,811	1925.....	372,468	40,890
1928.....	11,648,115	868,749	1926.....	271,674	31,118
1929.....	15,648,058	1,000,559	1927.....	264,544	31,703
Potassium iodide			1928.....	155,233	18,596
1923.....	24	\$ 140	1929.....	15,462	2,252
1924.....	47	210	Potassium sulfate, crude		
1925.....	43	263	1923.....	63,741	\$2,599,695
1926.....	10	75	1924.....	75,696	2,858,063
1928.....	4	16	1925.....	68,952	2,686,408
1929.....	1,262	5,181	1926.....	69,873	2,823,058



U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Potassium sulfate, crude ( <i>Cont.</i> )			1928.....	174,400	\$109,613
1927.....	68,904	\$2,947,969	1929.....	197,138	91,028
1928.....	86,458	3,908,221	Ounces.		
1929.....	79,510	3,647,839	Quinine, other salts & derivatives*		
Tons.			1924.....	271,306	\$134,491
Procaine, <i>see</i> Novocaine			1925.....	337,585	136,977
Propylene chlorohydrin, dichloride, & glycol*			1926.....	122,828	62,232
1926.....	231	\$311	1927.....	194,678	91,893
1927.....	4,409	504	1928.....	165,696	73,392
Pyridine*			1929.....	107,726	48,389
1924.....	641,689	\$278,254	Ounces.		
1925.....	661,791	303,353	Quinine sulfate		
1926.....	964,935	483,803	1923.....	2,992,828	\$1,493,158
1927.....	418,359	181,106	1924.....	1,210,086	557,714
1928.....	29,281	9,150	1925.....	1,558,822	696,943
1929.....	58,612	8,591	1926.....	1,584,171	655,437
Pyrites			1927.....	1,915,369	734,004
1923.....	263,695	\$1,254,369	1928.....	1,809,132	643,710
1924.....	246,786	598,642	1929.....	2,471,978	854,944
1925.....	276,385	773,925	Ounces.		
1926.....	366,150	856,981	Radium salts*		
1927.....	250,794	647,512	1923.....	80	\$268,646
1928.....	456,832	1,134,163	1924.....	116	417,758
1929.....	514,336	1,507,648	1925.....	141	452,811
Long tons.			1926.....	126	306,470
Pyroxylin compounds & other cellulose esters*			1927.....	174	571,863
1923.....	—	\$ 629,972	1928.....	144	486,411
1924.....	—	1,748,420	1929.....	153	526,890
1925.....	—	1,469,323	Grains.		
1926.....	—	2,306,646	Red lead		
1927.....	—	2,800,443	1923.....	3,600	\$ 220
1928.....	—	2,627,782	1924.....	1,874	155
1929.....	405,418	405,795	1925.....	3,452	268
Quicksilver, <i>see</i> Mercury			1926.....	9,591	817
Quinidine & salts*			1927.....	51,688	4,403
1924.....	415,011	\$ 20,985	1928.....	24,675	1,510
1925.....	12,208	7,496	1929.....	10,197	745
1926.....	126,740	38,470	Red oil, <i>see</i> Acid, oleic		
1927.....	40,500	24,207	Resorcinol, medicinal*		
1928.....	67,000	24,401	1923.....	6,720	\$ 8,390
1929.....	224,100	121,139	1925.....	14,525	18,824
Ounces.			1926.....	7,622	9,901
Quinine alkaloid*			1927.....	6,340	13,390
1924.....	165,700	\$ 94,538	1928.....	6,606	10,269
1925.....	163,000	86,541	1929.....	19,464	28,826
1926.....	9,788	6,765	Resorcinol, nonmedicinal*		
1927.....	279,390	153,243	1924.....	8,040	\$11,946
			1925.....	7,770	10,490
			1926.....	17,640	23,808

1927.....	18,869	\$24,359
1928.....	45,820	54,335
1929.....	37,004	46,228

Rochelle salt, *see* Potassium-sodium tartrate

Rosin, gum\*

1923.....	494,430	\$ 20,455
1924.....	591,512	21,801
1925.....	841,068	33,361
1926.....	13,027,148	689,984
1927.....	9,376,568	176,842
1928.....	1,040,699	40,417
1929.....	1,691,406	72,636

Saccharides\*

1924.....	15,833	\$13,784
1925.....	15,775	20,138
1926.....	8,928	13,208
1927.....	18,070	22,660
1928.....	372,882	58,085
1929.....	250,321	43,042

Saccharin\*

1923.....	1	\$14
1925.....	51	17

Sal ammoniac, *see* Ammonium chloride

Sal soda, *see* Soda, hydrated

Salicin\*

1923.....	2,618	\$6,641
1924.....	7,370	2,351
1925.....	19,684	4,308
1926.....	29,318	5,518
1927.....	25,088	4,089
1928.....	27,559	5,023
1929.....	34,604	6,583

In ounces after 1924.

Salol\*

1929.....	21	\$105
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Salt, *see* Sodium chloride

Saltpeter, *see* Potassium nitrate, crude

Salvarsan, arsphenamine, & similar arsenicals\*

1924.....	4	\$ 35
1926.....	2,229	26,032
1927.....	22	2,541
1928.....	138	12,301
1929.....	23	10,275

Satin white & precipitated calcium sulfate\*

1926.....	2,478	\$86
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1927.....	2,632	\$110
1928.....	970	35
1929.....	5,704	244

Selenium & salts\*

1923.....	935	\$ 1,636
1924.....	305	626
1925.....	2,227	3,726
1926.....	11,450	20,934
1927.....	17,908	33,427
1928.....	17,611	32,521
1929.....	12,097	21,634

Sheep dip\*

1923.....	103,952	\$ 6,549
1924.....	92,509	6,781
1925.....	120,532	10,351
1926.....	96,988	9,493
1927.....	125,525	13,485
1928.....	136,200	13,755
1929.....	187,603	20,055

Siennas, crude\*

1923.....	2,867,886	\$103,713
1924.....	1,555,650	46,733
1925.....	1,632,544	41,194
1926.....	1,935,778	48,837
1927.....	1,745,802	43,321
1928.....	1,485,390	39,771
1929.....	1,456,481	46,665

Soda, caustic, *see* Sodium hydroxide

Soda, hydrated (sal soda)\*

1923.....	12,500	\$1,752
1924.....	60	6
1925.....	30,123	2,281
1926.....	46,518	1,602
1927.....	13,660	439
1928.....	35,168	1,001
1929.....	488	90

Soda ash (carbonate, calcined)\*

1923.....	1,529,334	\$ 22,556
1924.....	1,854,511	21,151
1925.....	259,586	6,203
1926.....	140,585	7,362
1927.....	108,112	4,910
1928.....	75,508	2,696
1929.....	12,327,358	149,695

Sodium acetate\*

1924.....	119,903	\$ 5,116
1925.....	403,451	15,534
1926.....	537,327	25,950
1927.....	955,574	59,701
1928.....	1,534,125	64,763
1929.....	649,137	39,527

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Sodium arsenate*			1928.....	1,959,493	\$60,758
1923.....	2,671	\$ 360	1929.....	5,578,535	212,686
1924.....	21,168	2,315	Sodium chloride		
1925.....	16,217	1,559	1923.....	88,750	\$383,258
1926.....	145,452	9,613	1924.....	88,938	324,092
1927.....	92,655	5,468	1925.....	85,788	316,827
1928.....	11,012	644	1926.....	55,964	202,243
1929.....	24,048	1,502	1927.....	44,968	167,675
Sodium benzoate*			1928.....	42,856	149,559
1925.....	110	\$ 43	1929.....	36,449	131,716
1929.....	4,400	1,192	Short tons.		
Sodium bicarbonate*			Sodium chromate & bichromate*		
1923.....	47,415	\$1,470	1923.....	527	\$ 108
1924.....	7,396	466	1924.....	77	19
1925.....	11,244	702	1925.....	50	10
1926.....	20,925	1,345	1926.....	171	36
1927.....	62,348	2,185	1927.....	56,011	1,495
1928.....	81,389	3,948	1928.....	380	96
1929.....	2,780	307	1929.....	1,592	241
Sodium bisulfate (niter cake)*			Sodium compounds, n.e.s.*		
1924.....	55,126	\$1,043	1928.....	396,078	\$48,823
1925.....	1,067	55	1929.....	449,088	38,144
1926.....	53	8	Sodium cyanide		
1927.....	4,620	271	1923.....	30,138,869	\$2,472,735
1929.....	44,487	443	1924.....	29,832,655	2,664,784
Sodium bisulfite*			1925.....	30,212,294	2,600,200
1924.....	122,843	\$ 3,918	1926.....	31,804,378	2,557,900
1925.....	366,715	10,452	1927.....	32,598,801	2,607,945
1926.....	561,179	15,640	1928.....	37,616,558	2,933,963
1927.....	1,773,354	44,947	1929.....	40,047,033	3,198,914
1928.....	1,634,775	38,784	Sodium ferrocyanide (yellow prus-		
1929.....	1,790,234	41,068	siate)		
Sodium borate, <i>see</i> Borax, refined			1923.....	1,045,808	\$170,344
Sodium bromide			1924.....	3,159,979	268,055
1923.....	114,341	\$ 10,574	1925.....	1,651,484	117,322
1924.....	713,659	110,215	1926.....	814,891	55,459
1925.....	208,434	52,230	1927.....	1,786,688	143,345
1926.....	212,365	73,313	1928.....	1,624,586	136,431
1927.....	1,102	370	1929.....	1,939,502	168,453
1929.....	110	51	Sodium fluoride*		
Sodium carbonate, <i>see</i> Soda, hydrated;			1927.....	990,978	\$56,104
Soda ash			1928.....	1,162,155	65,275
Sodium chlorate*			1929.....	1,187,841	85,689
1923.....	1,612,958	\$64,104	Sodium formate*		
1924.....	732,967	28,226	1927.....	40,603	\$2,565
1925.....	813,168	30,252	1928.....	20,212	1,179
1926.....	1,485,980	52,981	Sodium hydrosulfite & compounds*		
1927.....	1,703,094	60,758	1923.....	674,131	\$85,276
			1924.....	447,893	83,307

1925.....	420,253	\$88,329	Sodium sulfate, anhydrous	
1926.....	216,172	47,772	1923.....	84 \$ 648
1927.....	225,231	52,135	1924.....	133 4,443
1928.....	285,686	51,007	1925.....	136 3,700
1929.....	289,605	54,453	1926.....	1,413 35,946
Sodium hydroxide (caustic)*			1927.....	2,877 65,695
1923.....	118,300	\$12,027	1928.....	3,578 79,742
1924.....	42,989	4,417	1929.....	5,552 116,935
1925.....	70,905	8,813	Short tons.	
1926.....	55,607	7,441	Sodium sulfate, crude (salt cake)	
1927.....	207,819	35,937	1923.....	4,717 \$ 84,051
1928.....	47,122	10,126	1924.....	3,060 40,582
1929.....	157,978	20,144	1925.....	1,708 18,176
Sodium nitrate			1926.....	5,598 66,321
1923.....	891,679	\$41,955,770	1927.....	9,975 100,279
1924.....	986,608	47,169,496	1928.....	25,203 253,553
1925.....	1,112,226	52,530,877	1929.....	91,633 829,793
1926.....	914,298	42,781,386	Short tons.	
1927.....	748,782	30,132,158	Sodium sulfate, crystalline (Glauber's salt)	
1928.....	1,032,911	36,990,861	1923.....	9,013 \$100,145
1929.....	930,458	34,913,254	1924.....	6,428 68,315
Tons.			1925.....	6,762 77,150
Sodium nitrite			1926.....	3,530 38,303
1923.....	4,685,527	\$209,029	1927.....	3,145 31,210
1924.....	4,511,339	178,365	1928.....	1,555 17,651
1925.....	1,971,015	78,149	1929.....	1,161 9,517
1926.....	1,927,189	59,575	Short tons.	
1927.....	291,726	10,809	Sodium sulfhydrate*	
1928.....	107,739	4,158	1927.....	2,631,669 \$65,209
1929.....	312,260	11,847	1928.....	296,357 6,923
Sodium phosphates			Sodium sulfide	
1923.....	1,661,562	\$ 46,055	1923.....	15,696,591 \$422,817
1924.....	1,818,222	45,028	1924.....	1,179,454 29,488
1925.....	4,500,220	101,908	1925.....	4,070,903 90,618
1926.....	9,055,458	227,932	1926.....	8,605,229 180,069
1927.....	16,770,555	395,402	1927.....	10,402,809 212,127
1928.....	19,663,905	440,743	1928.....	9,213,024 183,357
1929.....	17,637,072	456,138	1929.....	9,965,379 167,940
Sodium silicate (water glass)*			Sodium sulfite	
1923.....	1,050,735	\$23,187	1923.....	1,437,092 \$35,323
1924.....	384,688	7,248	1924.....	548,525 13,658
1925.....	243,561	6,949	1925.....	492,549 13,790
1926.....	224,716	4,701	1926.....	885,629 25,588
1927.....	203,317	4,003	1927.....	1,001,147 29,740
1928.....	109,664	2,279	1928.....	995,364 30,699
1929.....	299,209	6,327	1929.....	890,622 25,356
Sodium silicofluoride			Sodium sulfoxylate*	
1926.....	3,177,976	\$ 93,221	1924.....	22,456 \$ 546
1927.....	3,235,982	95,872	1925.....	6,052 1,640
1928.....	3,585,935	125,288	1926.....	4,365 979
1929.....	4,459,348	233,066	1928.....	648 160

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Sodium thiosulfate*			Sulfur, n.e.s.*		
1924.....	797,621	\$11,893	1924 (July-Dec.)	4,878,740	\$123,018
1925.....	221,280	3,693	1925.....	3,116,288	72,485
1926.....	71,296	1,445	1926.....	333,334	14,398
1927.....	131,714	2,446	1927.....	249,801	23,908
1928.....	33,737	652	1928.....	235,403	23,641
1929.....	42,863	1,041	1929.....	731,367	35,146
Strontium carbonate (strontianite) & sulfate (celestite)*			Tanning extracts, n.e.s.*		
1924.....	3,473,949	\$12,872	1924.....	413,324	\$29,285
1925.....	3,190,208	14,133	1925.....	553,989	27,888
1926.....	3,808,195	46,405	1926.....	602,904	34,969
1927.....	2,817,844	57,559	1927.....	235,883	9,843
1928.....	2,050,051	44,748	1928.....	206,755	12,252
1929.....	1,695,241	35,394	1929.....	26,704	1,153
Strontium carbonate, precipitated*			Tanning materials, coal-tar*		
1924.....	13,830	\$1,388	1926.....	665	\$1,081
1925.....	44,359	1,451	1927.....	99	336
1926.....	51,481	1,681	Tanning materials, crude, n.e.s.*		
1927.....	32,051	1,630	1923.....	6,638,550	\$94,291
1928.....	40,923	2,737	1924.....	9,940,403	78,625
1929.....	100,514	6,626	1925.....	7,635,131	83,678
Strontium nitrate*			1926.....	4,702,305	32,644
1924.....	1,209,974	\$ 79,844	1927.....	4,790,273	35,571
1925.....	2,098,410	120,731	1928.....	1,628,937	13,899
1926.....	688,913	36,611	1929.....	607,673	5,410
1927.....	1,816,053	101,316	Tartar emetic*		
1928.....	1,530,833	89,393	1924.....	15,145	\$3,088
1929.....	2,240,587	126,184	1925.....	5,180	898
Strontium oxide*			1927.....	16,211	2,905
1923.....	23,285	\$1,143	1928.....	9,134	1,664
1925.....	663	120	Terpin hydrate*		
1926.....	4,400	303	1923.....	443	\$ 214
1927.....	2,204	320	1925.....	1,250	283
1929.....	4,410	482	1927.....	4,470	1,004
Strychnine salts, n.e.s.*			1928.....	17,098	4,309
1923.....	165,730	\$136,751	1929.....	45,379	10,787
1924.....	84,367	61,102	Tetrachloroethane*		
1925.....	64,151	26,688	1924.....	263,954	\$10,427
1926.....	80,417	34,145	1925.....	493,185	17,307
1927.....	24,008	7,890	1926.....	16,536	989
1928.....	1,000	507	1927.....	70,173	3,585
1929.....	7,008	2,599	1928.....	53,436	2,937
Ounces.			1929.....	111,127	5,101
Strychnine sulfate*			Theobromine & salts*		
1924.....	11,291	\$ 5,592	1924.....	209	\$510
1925.....	16,341	7,094	1925.....	440	956
1926.....	36,583	14,458	Not stated after 1925.		
1927.....	42,000	11,702			
1929.....	21,164	7,250			
Ounces.					

<b>Thiocarbanilide*</b>			<b>Tribromophenol*</b>		
1925.....	1,496	\$2,510	1929.....	1,000	\$875
<b>Thorium nitrate*</b>			<b>Trichloroethylene*</b>		
1923.....	34,192	\$38,840	1924.....	308,673	\$14,481
1924.....	13,758	14,288	1925.....	222,192	8,689
1925.....	13,248	13,589	1927.....	1,321	92
1926.....	34,508	40,285	1928.....	85,737	5,257
1927.....	8,350	11,862	1929.....	205,928	10,909
1928.....	12,590	14,488	<b>Turmeric*</b>		
1929.....	9,214	10,858	1923.....	798,032	\$36,014
<b>Thorium oxide &amp; other salts*</b>			1924.....	1,290,832	89,304
1923.....	8,953	\$9,765	1925.....	1,084,448	82,334
1925.....	583	626	1926.....	1,027,608	71,027
1926.....	689	778	1927.....	1,125,891	47,025
1928.....	302	377	1928.....	759,031	30,441
1929.....	388	249	1929.....	796,216	50,881
<b>Thymol*</b>			<b>Turpentine, gum</b>		
1923.....	8,148	\$22,738	1923.....	156,397	\$158,329
1924.....	10,315	21,548	1924.....	177,675	132,616
1925.....	22,757	62,740	1925.....	287,379	212,597
1926.....	25,336	67,870	1926.....	306,586	195,655
1927.....	22,754	52,183	1927.....	315,453	191,754
1928.....	17,038	31,096	1928.....	342,528	170,756
1929.....	19,531	33,358	1929.....	402,488	208,068
<b>Tin bichloride, tetrachloride, &amp; other compounds*</b>			<b>Gallons.</b>		
1923.....	2,451,917	\$99,402	<b>Turpentine, spirits*</b>		
1924.....	149,830	8,191	1923.....	145,148	\$144,114
1925.....	12,846	2,793	1924.....	153,394	125,391
1926.....	92,291	11,727	1925.....	222,486	161,768
1927.....	134,976	44,606	1926.....	300,855	220,775
1929.....	5,193	783	1927.....	351,398	203,169
<b>Titanium-potassium oxalate &amp; compounds*</b>			1928.....	289,612	156,639
1924.....	13,201	\$ 1,904	1929.....	377,183	190,432
1925.....	75,033	12,917	<b>Gallons.</b>		
1926.....	80,452	11,979	<b>Ultramarine</b>		
1927.....	64,831	9,868	1923.....	641,765	\$ 84,501
1928.....	111,799	16,981	1924.....	853,161	108,916
1929.....	122,496	29,777	1925.....	960,335	143,596
<b>Tolidine, toluenesulfochloride, etc.*</b>			1926.....	869,528	118,562
1925.....	23,056	\$ 3,090	1927.....	916,964	113,662
1926.....	2,329	1,909	1928.....	932,210	113,049
1927.....	19,760	7,887	1929.....	683,149	81,285
1928.....	121,390	50,867	<b>Umbers, crude*</b>		
1929.....	27,763	12,322	1923.....	9,168,941	\$80,580
<b>Toluene*</b>			1924.....	5,676,868	55,233
1925.....	73,400	\$2,642	1925.....	6,570,820	46,568
1926.....	29,064	1,797	1926.....	6,744,899	46,903
1927.....	154	55	1927.....	5,362,765	36,142
			1928.....	7,400,838	44,722
			1929.....	6,837,881	42,513

U. S. IMPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Umbers, washed*			1925.....	46,385,585	\$153,507
1924.....	1,111,058	\$28,309	1926.....	42,999,399	142,075
1925.....	1,109,722	24,061	1927.....	26,132	160,505
1926.....	1,333,171	48,693	1928.....	31,220	185,465
1927.....	1,237,456	28,259	1929.....	35,874	177,940
1928.....	1,070,698	26,841	In tons after 1926.		
1929.....	1,226,985	28,741	Xylene*		
Urea*			1925.....	72,300	\$ 2,620
1923.....	195,208	\$ 40,275	1926.....	192,590	11,381
1924.....	66,318	9,642	1927.....	288,300	13,813
1925.....	101,291	12,406	1928.....	216,300	8,733
1926.....	302,783	27,308	1929.....	214,260	7,219
1927.....	657,243	43,591	Xylidine*		
1928.....	768,438	47,508	1923.....	150	\$60
1929.....	2,994,430	159,956	1929.....	5	48
Vanillin			Zinc chloride		
1928.....	18,759	\$129,917	1923.....	1,102,485	\$44,164
1929.....	20,703	137,579	1924.....	637,191	28,911
Verdigris (copper acetate & subacetate)*			1925.....	938,227	50,712
1923.....	26,278	\$ 4,727	1926.....	1,135,256	51,605
1924.....	62,306	4,787	1927.....	939,301	40,069
1925.....	98,215	10,111	1928.....	1,125,937	47,185
1926.....	49,945	6,136	1929.....	1,275,053	50,324
1927.....	28,325	3,656	Zinc oxide		
1928.....	25,638	4,079	1923.....	2,072,891	\$169,415
1929.....	34,993	8,563	1924.....	3,405,186	229,629
Vermilion reds, with mercury*			1925.....	2,548,888	205,582
1923.....	48,783	\$ 39,284	1926.....	2,254,922	198,987
1924.....	88,551	65,867	1927.....	2,797,024	220,427
1925.....	145,405	125,342	1928.....	2,696,585	208,557
1926.....	147,411	135,773	1929.....	2,756,214	230,225
1927.....	182,188	187,444	Zinc sulfate		
1928.....	77,934	103,786	1923.....	40,386	\$ 3,466
1929.....	95,090	125,198	1924.....	25,015	1,265
White arsenic, <i>see</i> Acid, arsenious			1925.....	34,047	1,368
White lead			1926.....	131,830	4,590
1923.....	336,892	\$31,386	1927.....	409,051	9,390
1924.....	141,156	13,478	1928.....	1,365,472	28,866
1925.....	213,028	21,535	1929.....	1,818,662	32,127
1926.....	297,117	31,510	Zinc sulfide*		
1927.....	330,421	29,901	1923.....	24,036	\$9,374
1928.....	166,236	15,889	1924.....	8,044	4,562
1929.....	196,478	19,086	1925.....	5,338	4,534
Whiting (Paris white)*			1926.....	15,947	6,087
1923.....	40,446,737	\$149,636	1927.....	42,611	9,100
1924.....	46,301,120	146,651	1928.....	213,441	32,934
			1929.....	607,482	78,286

## Appendix VI

## U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (pounds)

(From Chemical Foundation &amp; O.P.D. Repr.)

Starred (\*) items for fiscal years ending June 30th, remaining for calendar years; n.e.s. = not elsewhere specified; n.s.p.f. = not specially provided for. All data from official sources; where missing, not available.

Acetate, amyl, ethyl, & butyl*			Acid phosphates, <i>see</i> Superphosphate		
1928.....	274,357	\$ 43,544	Acids & anhydrides, n.e.s.*		
1929.....	903,292	178,405	1923.....	11,391,034	\$704,207
Acetone			1924.....	9,914,912	661,298
1928.....	4,959,104	\$426,656	1925.....	12,491,377	615,292
1929.....	7,897,230	708,199	1926.....	15,457,187	701,012
Acid, acetic*			1927.....	14,829,711	764,312
1922.....	5,079,880	\$367,365	1928.....	12,608,121	688,282
1923.....	3,633,767	290,081	1929.....	16,105,927	900,826
1924.....	486,674	64,666	Alcohol, ethyl, pure & denatured*		
1925.....	879,288	90,536	1923.....	404,837	\$170,155
1926.....	447,605	55,869	1924.....	312,187	213,298
Not stated after 1926.			1925.....	380,959	296,057
Acid, boric			1926.....	473,412	291,016
1923.....	891,670	\$104,915	1927.....	389,298	405,750
1924.....	727,082	79,081	1928.....	423,336	402,413
1925.....	766,234	78,158	1929.....	2,770,400	379,600
1926.....	1,414,655	125,777	In gallons prior to 1929.		
1928.....	3,382,183	189,627	Alcohol, methyl		
1929.....	5,203,881	180,381	1923.....	1,207,023	\$1,275,284
Acid, carbolic (phenol), <i>see</i> Phenol			1924.....	640,637	868,911
Acid, oleic			1925.....	408,185	321,308
1923.....	1,737,302	\$144,654	1926.....	417,265	311,508
1924.....	2,689,146	226,123	1927.....	311,272	263,010
1925.....	490,773	51,471	1928.....	523,810	375,314
1926.....	852,411	85,717	1929.....	498,481	403,475
1927.....	2,173,673	191,042	Gallons.		
1928.....	1,253,570	547,437	Aluminum sulfate		
1929.....	3,862,051	357,772	1923.....	35,610,560	\$505,732
Acid, stearic			1924.....	32,024,282	407,749
1923.....	2,862,918	\$368,179	1925.....	41,512,316	505,537
1924.....	2,198,298	255,410	1926.....	44,062,989	521,123
1925.....	1,931,374	282,761	1927.....	42,256,868	491,317
1926.....	1,011,540	139,054	1928.....	45,426,137	552,342
1927.....	2,352,659	240,013	1929.....	53,176,148	607,757
1928.....	2,260,542	257,178	Ammonia, anhydrous (liquid)		
1929.....	1,356,735	187,989	1928.....	1,907,867	\$314,990
Acid, sulfuric (50° Bé.) <i>see</i> Appendix XI			1929.....	2,329,458	374,281
			Ammonia & compounds*		
			1922.....	2,747,480	\$ 990,111
			1923.....	8,397,796	1,025,925



U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Ammonia & compounds* ( <i>Cont.</i> )			Bleaching powder		
1924.....	3,440,966	\$899,166	1923.....	28,828,428	\$525,436
1925.....	3,880,969	913,476	1924.....	21,602,125	380,156
1926.....	4,668,581	741,389	1925.....	27,389,007	472,497
1927.....	4,807,777	613,271	1926.....	20,858,158	387,972
1928.....	3,762,092	350,983	1927.....	16,686,586	310,652
1929.....	2,009,277	111,590	1928.....	21,869,528	369,589
			1929.....	5,023,960	127,767
Ammonium sulfate			Bone black*		
1923.....	152,784	\$11,117,726	1923.....	2,398,913	\$147,049
1924.....	118,367	6,918,589	1924.....	2,914,963	173,901
1925.....	123,141	6,748,728	1925.....	2,892,136	117,470
1926.....	181,125	9,823,847	Not stated separately after 1925.		
1927.....	138,692	6,826,600	Bone black & lampblack*		
1928.....	93,015	4,373,162	1926.....	3,194,613	\$225,737
1929.....	144,762	6,295,519	1927.....	3,327,498	225,351
Tons.			1928.....	3,322,883	192,887
Aniline oil & salt*			1929.....	3,751,230	236,314
1923.....	492,087	\$ 88,248	Borax, refined*		
1924.....	262,799	68,970	1923.....	32,400,617	\$1,375,387
1925.....	634,647	133,920	1924.....	36,475,491	1,611,258
1926.....	478,737	93,427	1925.....	32,527,339	1,482,570
Not stated after 1926.			1926.....	33,277,473	1,519,740
Baking powder*			1927.....	40,772,138	1,509,642
1923.....	4,061,789	\$1,773,005	1928.....	131,614,024	3,689,643
1924.....	3,930,204	1,622,749	1929.....	117,945,306	2,494,351
1925.....	4,274,684	1,628,120	Calcium acetate		
1926.....	4,084,663	1,500,125	1923.....	21,951,387	\$806,857
1927.....	4,790,031	1,791,860	1924.....	23,166,759	733,137
1928.....	5,122,950	1,775,224	1925.....	22,038,213	684,577
1929.....	5,701,122	1,931,682	1926.....	18,588,831	624,446
Bauxite & other aluminum ores & concentrates*			1927.....	11,633,785	409,060
1923.....	49,234	\$2,312,344	1928.....	11,172,685	373,278
1924.....	81,833	3,765,069	1929.....	101,198	6,518
1925.....	78,286	4,042,557	Calcium arsenate		
1926.....	81,877	4,142,048	1928.....	1,178,702	\$ 67,151
1927.....	107,930	6,742,126	1929.....	3,139,633	171,123
1928.....	122,489	6,964,234	Calcium carbide		
1929.....	126,952	4,118,566	1923.....	4,122	\$384,166
Tons.			1924.....	4,834	428,492
Benzene			1925.....	2,427	208,354
1923.....	15,189,185	\$3,647,660	1926.....	2,267	184,094
1924.....	7,896,610	1,739,837	1927.....	2,437	197,361
1925.....	8,034,126	1,748,034	1928.....	1,873	173,382
1926.....	19,580,870	5,513,173	1929.....	2,172	185,019
1927.....	25,793,566	6,665,105	Short tons.		
1928.....	21,338,429	4,962,719	Calcium chloride		
1929.....	33,346,381	8,536,878	1929.....	30,850,858	\$362,658

<b>Carbon black</b>			1928.....	2,447,000	\$248,763
1923.....	29,020,743	\$4,723,166	1929.....	2,717,509	404,002
1924.....	34,428,855	3,385,852	<b>Coal-tar medicinals*</b>		
1925.....	43,182,635	3,555,769	1923.....	217,784	\$138,526
1926.....	39,210,389	3,622,907	1924.....	247,562	233,817
1927.....	54,430,811	4,599,734	1925.....	504,127	410,257
1928.....	77,903,153	6,794,224	1926.....	658,831	409,764
1929.....	91,829,215	8,270,837	1927.....	885,729	378,295
<b>Chestnut extract</b>			1928.....	593,696	323,130
1923.....	8,714,834	\$307,579	1929.....	514,541	228,435
1924.....	9,275,657	290,728	<b>Coal-tar photographic chemicals*</b>		
1925.....	7,286,552	216,644	1922.....	248,119	\$103,853
1926.....	6,176,455	174,590	1923.....	216,011	94,285
1927.....	5,874,805	176,019	1924.....	183,075	96,661
1928.....	10,651,519	351,392	1925.....	229,473	81,523
1929.....	5,065,458	133,734	1926.....	415,128	119,951
<b>Chlorine</b>			Not stated after 1926.		
1928.....	5,493,057	\$234,931	<b>Copper sulfate (blue vitriol)</b>		
1929.....	7,168,016	256,667	1923.....	2,290,905	\$130,213
<b>Chrome colors &amp; iron blues*</b>			1924.....	2,988,039	142,626
1929.....	168,985	\$17,642	1925.....	6,139,344	285,870
<b>Coal tar, crude*</b>			1926.....	4,798,620	231,175
1928.....	66,664	\$253,829	1927.....	6,206,904	320,653
1929.....	113,104	488,718	1928.....	8,666,899	455,023
280 lb. barrels.			1929.....	6,419,688	368,481
<b>Coal-tar colors, dyes, &amp; stains, n.e.s.*</b>			<b>Dye extracts, n.e.s.*</b>		
1923.....	13,935,567	\$5,011,825	1923.....	2,776,378	\$393,815
1924.....	17,105,265	5,407,652	1924.....	1,649,951	234,820
1925.....	20,683,472	6,591,543	1925.....	1,342,439	162,021
1926.....	25,101,464	6,042,748	1926.....	1,184,530	126,889
1927.....	26,605,220	5,829,412	1927.....	966,442	144,603
1928.....	25,782,028	5,556,030	1928.....	1,013,918	107,561
1929.....	34,099,779	7,245,577	1929.....	639,855	78,530
<b>Coal-tar distillates, crude, n.e.s.*</b>			<b>Dyeing &amp; tanning materials, crude*</b>		
1923.....	8,160,098	\$236,405	1923.....	840	\$ 74,017
1924.....	10,159,483	367,108	1924.....	1,657	106,542
1925.....	16,652,904	483,801	1925.....	5,897	137,349
1926.....	24,919,275	783,740	1926.....	4,298	78,509
1927.....	21,093,192	525,809	1927.....	1,538	77,717
1928.....	13,847,137	412,085	1928.....	2,262	107,359
1929.....	14,798,624	457,657	1929.....	2,292	79,029
<b>Coal-tar dyes, packaged*</b>			Tons.		
1928.....	157,967	\$124,345	<b>Ferroalloys, tungsten, manganese, etc., n.e.s.*</b>		
1929.....	290,073	210,327	1923.....	1,078	\$58,049
<b>Coal-tar intermediates, n.e.s.*</b>			1924.....	1,582	67,301
1923.....	1,371,649	\$273,628	Tons; not stated after 1924.		
1924.....	1,802,689	302,710	<b>Ferrovanadium*</b>		
1925.....	1,854,442	294,493	1923.....	37,440	\$ 50,529
1926.....	1,240,567	250,847	1924.....	74,020	103,544
1927.....	2,459,529	432,270	1925.....	18,933	24,108
			Not stated after 1925.		

U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Fertilizers, n.e.s.*			Lampblack*		
1923.....	43,988	\$1,784,529	1923.....	18,157,775	\$2,730,565
1924.....	35,474	1,455,073	1924.....	37,563,672	4,929,142
1925.....	48,227	2,110,393	1925.....	35,302,783	4,058,759
1926.....	56,161	2,462,459	Not stated separately after 1925.		
1927.....	80,677	3,420,942	Lead arsenate		
1928.....	100,933	4,368,250	1928.....	1,093,673	\$141,235
1929.....	102,281	4,258,787	1929.....	1,563,982	192,185
Tons.			Lead carbonate, basic, <i>see</i> White lead		
Fertilizers, nitrogenous, n.e.s.*			Lime*		
1923.....	10,805	\$466,229	1923.....	110,142	\$152,671
1924.....	5,749	339,426	1924.....	129,394	194,613
1925.....	6,114	340,700	1925.....	143,686	195,757
1926.....	6,298	338,834	1926.....	142,942	216,898
1927.....	9,324	572,823	1927.....	150,161	206,408
1928.....	8,547	412,165	1928.....	157,558	214,667
1929.....	17,831	845,244	1929.....	189,726	262,801
Tons.			200 lb. barrels.		
Fertilizers, potash materials*			Lime, chlorinated, <i>see</i> Bleaching powder		
1929.....	6,713	\$263,670	Lithopone		
Tons.			1923.....	2,970,743	\$176,624
Fertilizers, prepared mixtures*			1924.....	1,845,073	104,783
1923.....	14,036	\$ 601,870	1925.....	2,573,354	132,771
1924.....	34,129	1,650,391	1926.....	3,881,329	200,412
1925.....	26,945	1,294,124	1927.....	4,219,532	222,585
1926.....	31,921	1,387,068	1928.....	6,651,523	337,565
1927.....	15,877	675,990	1929.....	9,112,038	463,235
1928.....	24,907	928,039	Logwood extract		
1929.....	25,280	1,504,036	1923.....	1,954,098	\$264,207
Tons.			1924.....	1,483,953	189,052
Formaldehyde			1925.....	2,225,358	251,640
1923.....	3,336,983	\$429,546	1926.....	1,862,306	204,137
1924.....	2,897,822	322,214	1927.....	2,724,155	253,236
1925.....	2,799,116	291,156	1928.....	2,099,035	208,818
1926.....	2,386,536	225,923	1929.....	2,025,351	208,437
1927.....	2,235,960	207,262	Lye*		
1928.....	2,368,086	199,357	1929.....	674,765	\$31,504
1929.....	2,588,169	225,229	Magnesium salts*		
Glycerin			1929.....	263,578	\$12,662
1923.....	1,767,407	\$318,765	Mercury		
1924.....	1,415,882	237,639	1923.....	23,827	\$25,195
1925.....	1,367,191	282,078	1924.....	15,581	14,333
1926.....	767,698	192,220	1925.....	15,289	15,930
1927.....	693,144	143,700	1926.....	8,668	10,319
1928.....	2,051,937	259,100	Methyl alcohol, <i>see</i> Alcohol, methyl		
1929.....	1,373,605	197,986			
Hydrogen peroxide					
1929.....	2,237,940	\$382,566			

<b>Naphthalene*</b>			<b>Potassium bichromate*</b>		
1923.....	109,514	\$12,657	1923.....	3,484,876	\$318,220
1924.....	95,164	10,386	1924.....	1,574,674	142,695
Not stated after 1924			1925.....	901,576	74,054
<b>Nickel oxide &amp; matte*</b>			1926.....	251,978	19,717
1923.....	306,000	\$26,642	Not stated after 1926.		
Not stated after 1923.			<b>Potassium chlorate*</b>		
<b>Nickel salts*</b>			1923.....	391,120	\$39,067
1929.....	32,512	\$5,041	1924.....	493,417	26,538
Not stated after 1924.			<b>Potassium compounds, n.e.s.*</b>		
<b>Nicotine sulfate*</b>			1923.....	4,232,193	\$199,778
1928.....	892,358	\$268,866	1924.....	3,261,590	156,391
1929.....	186,207	162,841	1925.....	2,477,853	274,359
<b>Oxygen*</b>			1926.....	3,545,149	317,670
1928.....	236,614	\$41,841	1927.....	3,086,564	352,102
1929.....	709,866	89,152	1928.....	13,194,831	791,160
<b>Phenol</b>			1929.....	4,855,184	614,655
1923.....	232,830	\$34,389	<b>Pyroxylin products (Celluloid, etc.)</b>		
1924.....	51,364	8,016	unmanufactured*		
<b>Phosphate rock, see Appendix XXII</b>			1923.....	1,790,701	\$2,232,074
<b>Pigments, chemical, n.e.s.*</b>			1924.....	1,756,210	1,991,701
1925.....	5,335,926	\$622,344	1925.....	2,629,360	2,371,849
1926.....	6,420,933	803,547	1926.....	2,300,144	1,770,968
1927.....	4,817,414	595,784	1927.....	1,700,967	1,320,616
1928.....	3,880,512	560,034	1928.....	2,391,481	1,915,984
1929.....	6,804,664	975,727	1929.....	3,556,084	2,314,784
<b>Pigments, mineral &amp; metallic*</b>			<b>Quicksilver, see Mercury</b>		
1923.....	29,458,942	\$1,025,438	<b>Quinine sulfate &amp; other cinchona salts*</b>		
1924.....	29,094,818	892,507	1923.....	365,852	\$160,366
1925.....	26,438,536	791,545	1924.....	326,282	164,149
1926.....	33,348,402	997,070	1925.....	637,373	215,258
1927.....	33,048,106	1,039,491	1926.....	314,825	162,682
1928.....	39,114,090	1,180,255	1927.....	274,837	127,847
1929.....	38,779,090	1,045,267	1928.....	247,620	110,586
<b>Plumbago or graphite, unmanufactured*</b>			1929.....	348,840	143,440
1923.....	1,197,760	\$100,782	<b>Ounces.</b>		
1924.....	2,003,891	147,613	<b>Red lead</b>		
1925.....	2,170,979	159,908	1923.....	3,680,663	\$372,828
1926.....	1,076,866	75,210	1924.....	1,880,263	210,598
Included in next class after 1926.			1925.....	1,604,497	183,591
<b>Plumbago or graphite, &amp; manufactures (except crucibles)*</b>			1926.....	1,550,364	175,273
1923.....	2,142,055	\$302,941	1927.....	2,857,581	271,376
1924.....	1,554,195	268,489	1928.....	4,167,918	364,995
1925.....	1,824,136	289,286	1929.....	5,780,147	503,243
1926.....	3,281,135	455,031	<b>Red lead, litharge &amp; orange mineral after 1926.</b>		
1927.....	4,133,254	480,236	<b>Red oil, see Acid, oleic</b>		
1928.....	3,733,918	391,892	<b>Rosin, gum</b>		
1929.....	4,188,204	476,660	1926.....	956,032	\$21,903,780
			1927.....	1,237,916	20,927,349

U. S. EXPORTS OF DRUGS, CHEMICALS, AND THEIR PRODUCTS, 1923-29 (*Cont.*)

Rosin, gum ( <i>Cont.</i> )			1926.....	158,908	\$1,277,790
1928.....	1,022,082	\$15,563,320	1927.....	153,832	1,329,980
1929.....	1,240,530	17,705,876	1928.....	145,396	1,185,682
500 lb. barrels.			1929.....	109,222	1,008,842
			Short tons.		
Rosin, wood			Sodium chromate & bichromate		
1926.....	138,290	\$2,729,530	1925.....	7,299,336	\$444,630
1927.....	143,773	2,155,121	1926.....	8,526,936	531,129
1928.....	152,111	2,053,360	1927.....	8,905,655	562,625
1929.....	196,888	2,736,514	1928.....	8,692,088	560,777
500 lb. barrels.			1929.....	5,855,293	396,855
Sal soda, <i>see</i> Soda, hydrated			Sodium cyanide		
Salt, <i>see</i> Sodium chloride			1923.....	5,005,952	\$473,675
Soda, caustic, <i>see</i> Sodium hydroxide			1924.....	4,210,172	489,524
Soda, hydrated (sal soda)*			1925.....	1,591,633	273,937
1923.....	12,185,928	\$186,550	1926.....	1,883,353	305,398
1924.....	12,784,299	194,172	1927.....	1,299,416	212,547
1925.....	12,459,512	176,515	1928.....	1,579,447	243,046
1926.....	13,618,569	192,211	1929.....	1,815,861	273,853
1927.....	12,746,736	163,288	Sodium hydroxide (caustic)		
1929.....	6,193,205	87,448	1923.....	57,342	\$3,827,403
Nor stated separately in 1928.			1924.....	46,058	2,862,809
Soda ash*			1925.....	50,477	2,995,724
1923.....	29,858,337	\$699,671	1926.....	51,647	3,111,510
1924.....	26,404,428	673,735	1927.....	50,443	2,994,469
1925.....	33,204,687	779,533	1928.....	59,707	3,487,832
1926.....	34,701,719	855,755	1929.....	60,538	3,516,023
1927.....	41,504,725	961,256	Tons.		
1929.....	33,668,482	589,159	Sodium salts, n.e.s.*		
Not stated separately in 1928.			1923.....	129,704,630	\$2,363,007
Sodium bicarbonate			1924.....	121,116,444	2,173,981
1923.....	16,934,348	\$387,861	1925.....	102,676,879	1,713,378
1924.....	15,223,786	333,337	1926.....	100,750,268	1,353,362
1925.....	17,297,561	350,585	1927.....	70,973,698	1,520,302
1926.....	19,338,710	372,700	1928.....	87,195,704	1,466,140
1927.....	18,287,460	338,155	1929.....	201,525,763	2,014,567
1928.....	18,711,148	344,974	Sodium silicate (water glass)		
1929.....	18,947,051	357,027	1923.....	16,552	\$316,543
Sodium borate, <i>see</i> Borax, refined			1924.....	16,353	301,571
Sodium carbonate (soda ash, sal soda, washing soda)*			1925.....	20,259	353,944
1928.....	56,871,504	\$1,175,242	1926.....	24,172	396,496
Stated separately before and after 1928.			1927.....	27,493	432,062
Sodium chloride			1928.....	29,663	642,073
1923.....	125,520	\$1,211,226	1929.....	33,367	617,265
1924.....	144,945	1,288,376	Short tons.		
1925.....	155,079	1,219,935	Sodium sulfate*		
			1929.....	1,720,774	\$32,432

<b>Sulfur, crude</b>			1925.....	11,557,221	\$11,346,464
1923.....	472,525	\$ 7,105,260	1926.....	11,586,590	10,636,166
1924.....	482,114	7,792,854	1927.....	15,810,172	9,504,902
1925.....	629,401	11,000,234	1928.....	12,507,098	6,675,276
1926.....	576,966	10,918,580	1929.....	16,304,145	8,530,431
1927.....	789,371	16,269,254	<b>Gallons.</b>		
1928.....	685,051	14,345,025	<b>Turpentine, wood</b>		
1929.....	855,183	17,628,813	1923.....	393,082	\$405,594
<b>Tons.</b>			1924.....	561,446	443,340
<b>Sulfur, refined</b>			1925.....	583,605	439,275
1923.....	4,367,090	\$110,847	1926.....	685,193	530,303
1924.....	4,546,009	101,347	1927.....	681,101	394,522
1925.....	6,381,791	153,546	1928.....	1,042,472	524,184
1926.....	12,002,105	236,146	1929.....	880,538	435,331
1927.....	31,419,221	544,373	<b>Gallons.</b>		
1928.....	44,536,508	706,766	<b>Turpentine substitutes (mineral spirits) *</b>		
1929.....	39,564,975	649,240	1924.....	1,063,893	\$425,245
<b>Superphosphates (acid phosphates)</b>			1925.....	941,047	274,794
1923.....	42,099	\$ 534,446	1926.....	1,415,607	348,931
1924.....	45,751	588,620	1927.....	2,788,719	562,335
1925.....	65,779	988,914	1928.....	1,874,609	444,725
1926.....	64,452	937,278	1929.....	2,625,299	573,037
1927.....	105,507	1,615,466	<b>Gallons.</b>		
1928.....	88,613	1,510,577	<b>White lead</b>		
1929.....	85,118	1,489,476	1923.....	10,344,069	\$ 836,261
<b>Tons.</b>			1924.....	10,109,455	853,444
<b>Tanning extracts, vegetable &amp; chemical (excluding chestnut) *</b>			1925.....	13,663,309	1,293,168
1923.....	24,942,925	\$1,174,108	1926.....	12,478,333	1,107,835
1924.....	23,400,416	1,148,249	1927.....	12,094,514	947,226
1925.....	21,063,238	1,152,431	1928.....	12,952,743	952,316
1926.....	22,976,856	1,188,242	1929.....	11,815,478	921,509
1927.....	24,819,816	1,284,137	<b>Zinc oxide</b>		
1928.....	40,518,892	2,088,936	1923.....	10,047,408	\$ 743,577
1929.....	32,080,666	1,724,901	1924.....	7,854,394	605,630
<b>Tanning materials, see Dyeing</b>			1925.....	21,710,048	1,503,561
<b>Turpentine, gum</b>			1926.....	29,322,592	1,917,420
1923.....	11,478,459	\$12,303,809	1927.....	28,988,818	1,812,786
1924.....	11,510,154	10,105,015	1928.....	29,598,165	1,849,889
			1929.....	35,275,134	2,301,643

## Appendix VII

REPORT OF THE JOINT COMMITTEE ON UNIFORM SALES CONTRACT  
FOR CHEMICALS

Although the shipment of chemicals on definite, agreed terms as to quantity and quality, price and delivery is advantageous alike to producer and consumer, nevertheless there has been growing dissatisfaction among both buyers and sellers with such sales. The wholesale cancellations that followed immediately after the signing of the Armistice; the short deliveries made during the period of advancing prices in 1920-21; the shifting prices introduced by protection against decline clauses during the recent period of deflation have all three combined to sap from the average chemical sales contract most of its practical advantages to both parties.

These advantages are chiefly assurances of stability. A legal, binding sales contract, fair in its terms and entered into in good faith, assures the chemical producer of an outlet for definite quantities of his goods and assures the chemical consumer of a supply of necessary materials. Such a contract enables producer and consumer both to plan a definite production program, to engage labor, to buy power, to adopt a profitable sales policy. Since chemicals are raw materials of every industry, and in the case of such important items as textiles, leather, rubber, paper, paints, fertilizers, and glassware they are one of the principal factors of cost, stability in our chemical markets is vital to the prosperity of the entire people. Nothing is so disturbing to this stability, so expensive to consumers and so ruinous to producers, as unsettled conditions surrounding contract sales.

The seriousness of this problem and its basic importance command the best thought and most active cooperation of all buyers and sellers. Many of the factors which, since 1914, have tended to undermine contract business are no longer dominant. The time is ripe for a concerted effort to put a solid foundation of known demand and assured supply, of guaranteed deliveries and staple price under our chemical markets. This can be achieved, if the bulk of our chemicals are sold upon a definite contract basis.

In this connection, the legal instrument under which these sales are made, the chemical sales contract itself, is the subject of first consideration.

A comparative study of the contracts of twenty leading chemical manufacturers by one of the chemical business papers revealed not only many forms and conflicting, confusing terms, but discovered also that many so-called contracts are, legally considered, only rather indefinite options.

One of the most unfair of all business documents is the average chemical sales contract. It usually protects the buyer against a decline in price: it never protects a seller against an advance. It is seldom enforceable against the buyer: it is binding as to deliveries on the seller. There is little truth in calling an option to buy a certain quantity of a given chemical over a period of time at the best market price a sales contract. An option is an opportunity, not an obligation to purchase; and boiled down to its real meaning, that is all most chemical sales contracts are. . . .

Something for something has been laid down always as a fundamental of all contracts. *Quid pro quo* is a principle of the law. Without just and proper equivalents many judges have thrown many contracts out of their courts.

Something for nothing is not equivalent.

To both the seller and the buyer there are plenty of advantages in a contract to buy goods for regular future delivery, and in the single item of price it is only a fair advantage if it can be shared. A fixed price protects the buyer against any advance and protects the seller against any decline. That is fair and reasonable.—*Drug Chem. Mkts.*, Dec. 13-27, 1922.

The National Association of Purchasing Agents, following the publication of these editorials, inquired whether the chemical industry would be interested in cooperating

with them in the movement they initiated to adopt standardized contracts, and this committee met at the invitation of its chairman informally to discuss this question.

It was unanimously agreed that a contract, applicable to the sale of all chemicals, could be drawn in conformity with the style and terms of the uniform contracts for coal and iron approved by the Purchasing Agents, and that such a contract would do much to improve contract conditions. It was the sense of the meeting also that more definite assurances on delivery could be given to buyers and that any clause protecting prices against decline is unfair and nullifies the legal standing of a sales instrument.

The Joint Committee organized and divided its work between two Committees appointed by the Chemical Manufacturers' Association [*sic.*] (Mr. Rigney, chairman) and the Salesmen's Association (Mr. Kienle, chairman).

Modeled after the standardized form of the coal and iron contracts, approved by the National Association of Purchasing Agents and endorsed by the Department of Commerce, a contract was drafted by the Salesmen's Committee upon the terms and conditions now used by chemical sellers. This draft was submitted to the Manufacturers' Committee and by them studied and revised. This revised contract was three times further revised by this Joint Committee. It has been scrutinized by the various companies and submitted by them to their attorneys for criticism and suggestion. The result of three months of this work is now placed before the industry.

The uniform sales contract which we present to you has been drawn carefully with the interests of both buyers and sellers in mind. Its form and style is that adopted in other great industries, thus making for the convenience of the purchasers. It contains no trick conditions and every effort has been made to remove any ambiguity that might result in misunderstanding. It is a legal document, more strict in many clauses than the majority of existing chemical contracts, but also more just. It can be used for the sale of any chemical—heavy, fine, or dye: imported or domestic—in any container by either maker, agent, or broker. Its general terms and conditions cover all necessary legitimate points and need not be modified at all to meet special conditions. There is, in fact, but one case which it does not meet completely, i.e., the sale of chemicals for further resale; and this may be covered either by erasing the phrase "for . . . use and consumption in factor . . . located at . . ." or by printing a special resale form with this phrase omitted from the preamble.

A word of particular warning must be sounded to companies that adopt this uniform contract. It must be adopted completely and without change. The standardized size of the paper, strongly endorsed by buyers and the Government for ready filing, is the letter sheet (8½ x 11 inches). While it is not desirable to give up all individuality of headings, type styles of firm names, etc., nevertheless the type and arrangement in the body and in the terms and conditions should be followed closely, and there must be absolutely no change whatever in actual wording or punctuation.

To facilitate this and to reduce the expense of printing contract forms, it has been proposed that the Salesmen's Association print them from plates, printing in the name of the chemical seller in distinctive type, and supply them at cost. If there is any general demand from the industry, it is likely that this organization will undertake this work.

That the general adoption of this uniform contract will be of immeasurable, direct benefit to both buyers and sellers of chemicals is obvious. It will be a great convenience to buyers. It will minimize the chances of misunderstandings. It will save time in explanation and scrutiny of terms. It will eliminate much unnecessary competition on terms of sale among the sellers. Its advantages have been well summarized by the Contract Committee of the Manufacturing Chemists' Association in their report to that organization:

Your Committee on uniform sales contract begs to submit herewith proposed form of contract to be used by the chemical industry in the United States. It is the unanimous opinion of your Committee that the adoption and general use of this form of contract will be a long step in the right direction and tend to create a better understanding in the industry.

After a very careful survey of the chemical industry your Committee is fully



satisfied that the practices of granting protection against decline in price is eminently unfair to the manufacturer, and its use not only unnecessary but undesirable. If it is absolutely necessary to provide for a modification of the price fixed in the contract, such modification should be based on the cost of raw material, and should not only protect the buyer against decline in price, but should allow the manufacturer to increase the contract price should the cost of raw material be advanced. This is a mutual proposition and the only form of price modification that can be defended by logical reasoning.

Practically all leading companies in the chemical industry have endorsed the idea of standardizing contract sales and the business and technical press has commented favorably upon the work of this Joint Committee, of which the following are representative examples:

It is as close to an ideal committee to consider this important matter as could well be selected.

The problem, which the committee has to face, is a large one. There have been numerous complaints in respect to the nature of the contract relation between manufacturers and consumers of chemicals. . . . But if there must be contracts, let them be equitable ones which give the buyer reasonable assurance of delivery and price and afford the seller the same advantages.—*J. Commerce*, Apr. 6, 1923.

The advantages of such a contract are apparent. To begin with, there is no good reason why a standard contract for heavy chemicals should not be adopted and put into operation. There are many reasons—reasons making for economy, efficiency, simplicity, and avoidance of possible misunderstandings—why a uniform contract should supersede the individual and sometimes widely varying contracts now in force.—*Chem. Met. Eng.*, Apr. 16, 1923.

Now is an opportune time to standardize chemical contract conditions. It has been due to the unusual competitive conditions of recent years that evils affecting adversely the interests of both producers and consumers have disturbed contract business. Speculative elements in the chemical trade, which have thrived on fluctuating prices, have largely been eliminated. The great overproduction induced by the war has been largely reduced since 1921. Hoarding of stocks by consumers has naturally been stopped. Chemical prices have been well deflated. Both buyers and sellers seek stability in the markets, as an advantage to each, and more stable contract conditions will do more to reach this end than anything else. The uniform contract, submitted herewith, will, we are confident be helpful in this, and we therefore, urge its prompt and hearty adoption.

There is no minority report.

Signed: JOINT COMMITTEE ON CONTRACTS: Williams Haynes, chmn.; Chas. M. Butterworth, John A. Chew, P. M. Dinkins, E. J. Barber, John W. Boyer, Ralph E. Dorland, George Eno, John A. Kienle, F. L. McCartney, Samuel Rigney, J. H. D. Roder, Philip S. Tilden, Chas. N. Turner, Milton C. Whitaker, S. W. Wilder.  
AGREEMENT entered into this ..... day of ..... 19...., between

#### THE JOHN DOE CHEMICAL COMPANY

the Seller and ..... the Buyer.

The Seller hereby agrees to sell and furnish and the Buyer agrees to purchase and accept the quantity and kind of the following materials required by the Buyer for ..... own use and consumption in factor ..... located at ..... during the period from ..... 19.... to ..... 19.... inclusive; at the price hereinafter stated and upon the terms and conditions herein contained, to wit:

ARTICLE:

QUALITY:

QUANTITY:

DELIVERY:

PRICE:

CONTAINER CHARGES:

## TERMS AND CONDITIONS

### 1. TERMS OF PAYMENT:

Invoices shall be paid in net cash, within thirty days of date of same, payment to be in U. S. gold coin or its equivalent. Noncompliance with said terms of payment shall give the Seller the right to suspend further shipments until all previous shipments are paid for; and if in the judgment of the Seller, the financial responsibility of the Buyer shall at any time become impaired, and written notice thereof be given by the Seller to the Buyer, the Seller shall have the right to suspend further shipments on this contract until adequate security for payment is furnished by the Buyer. If such security is not furnished within thirty days after the notice, the Seller shall have the right to cancel this agreement.

### 2. WEIGHTS:

Invoice weights and tares to govern.

### 3. DELIVERIES:

Each month's quota shall be considered as a separate and independent contract.

The Buyer shall give to the Seller orders covering shipment on or before the 15th day of the month previous to the month of shipment.

### 4. CONTINGENCIES:

In the event of war, fire, flood, strike, lockout, accident or other like cause beyond the control of the parties, interfering with the production, consumption, and transportation of the materials herein described, or the supply of any raw material of which the said materials are a product, deliveries under this contract may be suspended during the period required to remove the cause or repair the damage, and the total quantity deliverable under the contract shall be reduced in proportion to the duration of such suspension.

### 5. TAXES:

Any tax or other Governmental charge upon the production and/or sales and/or shipment of the materials herein specified becoming effective within the term of this agreement may, at the Seller's option, be added to the price herein provided.

### 6. CONTAINERS:

(a) The Buyer agrees to use Seller's returnable containers only for the reasonable storage of Seller's material originally shipped therein, and to return same, freight prepaid, within ..... days. In event containers are not returned in ..... days the Seller shall have the option of refusing to accept the same. All such containers will be charged at the Seller's regular prices and paid for at the same time as the contents, but credited at the price charged when returned as above provided.

(b) If the material covered by this contract is shipped in tankcars furnished by the Seller, the Buyer agrees that such tankcars will be unloaded within forty-eight (48) hours (Sundays and holidays excepted) after receipt thereof.

### 7. CLAIMS:

The Buyer agrees to make an examination and test on arrival, and that failure to give notice of claim within ten (10) days of arrival shall constitute a waiver by the Buyer of all claims.

## 8. AGREEMENTS:

No agreements or understandings not expressly stated herein shall be binding in the interpretation or fulfillment of this agreement.

This contract shall be binding upon, and enure to the benefit of the successors of the parties hereto respectively.

IN WITNESS WHEREOF the parties hereto have caused this agreement to be executed in duplicate the day and year first written above

..... Seller	..... Buyer
By .....	By .....
Address .....	Address .....

## Appendix VIII

DU PONT STOCKHOLDINGS OF \$500,000 AND OVER <sup>a</sup>

Associated Securities of Canada, Ltd., \$2,515,358, 100% control<sup>b</sup>; Compañía S. A. de Explosivos, \$1,030,743, 42.43% control; Du Pont Building Corp., \$1,500,000, 100% control; Du Pont Cellophane Co., \$810,333 common, 52% control; Du Pont Engineering Co., \$700,000, 100% control; Du Pont National Ammonia Co., \$2,657,849, 50.95% control; Du Pont Nitrate Co., \$945,000 common, \$1,175,000 preferred, 100% control; Du Pont Pathe Film Mfg. Corp., \$344,603 common, \$200,000 preferred, \$500,000 bonds, 51% control; Du Pont Rayon Co., \$2,763,152 common, \$3,467,610 preferred, 60% control; Du Pont Viscoloid Co., \$9,864,219 common, \$3,944,610 preferred, 79.44% control; Dynamit A.-G., \$892,671; I. G. Farbenindustrie, \$1,159,905, .05% control with Dynamit A.-G.<sup>c</sup>; E. I. du Pont de Nemours & Co., \$1,269,805 common, \$1,614,214 debenture; Eastern Alcohol Corp., \$928,700 common, 50% control; Equitable Powder Mfg. Corp., \$661,500, 49% control; General Motors Corp., \$119,774,640 common, 22.94% control<sup>d</sup>; Lazote, Inc., \$998,800, 17.15% control; U. S. Steel Corp., \$14,005,392 common, 1% control. *Total*: \$173,726,104.

<sup>a</sup> From Fed. Trade Comm., *Report on du Pont Investments*, 1929; <sup>b</sup> 39.69% common stock ownership in Canadian Industries; <sup>c</sup> % ownership in I.G. with Dynamit stock converted into I.G. stock; <sup>d</sup> Du Pont investment in General Motors Securities Co., latter, controlled by General Motors, voting additional 9.7% of General Motors.

## Appendix IX

GERMAN PRODUCTION OF CRUDE AND REFINED POTASH SALTS,  
1913, 1921, 1924-28

(From *Die Deutsche Kaliindustrie*, 1929.)

<i>Crude Salts Mined</i>	1913	1924	1925	1926	1927	1928
Quota-bearing shafts .....	164	221	224	228	228	229
Operating shafts .....	152	93	85	66	60	60
Output, 000 metric tons .....	11,957	8,091	12,085	9,498	11,070	12,488
Output/quota-bearing shaft, 000 metric tons .....	72.905	36.610	53.950	41.263	48.552	54.532
Output/operating shaft, 000 metric tons .....	78.661	87.000	142.176	142.545	184.500	208.133
No. workers .....	23,667	16,961	17,887	17,734	13,569	14,235
Output/man, metric tons .....	1.56	1.79	2.34	2.40	2.90	3.08
<i>Potash Salts Refined</i>	1921	1924	1925	1926	1927	1928
Factories in operation .....	75	57	49	34	32	31
Raw salts delivered to factories, 000 metric tons .....	6,985	6,443	9,623	7,391	8,626	10,152
Av. yearly K <sub>2</sub> O output/factory, 000 metric tons .....	9.6	13.3	24.1	27.2	36.6	43.0
No. workers .....	—	7,101	7,021	5,437	4,885	4,762
K <sub>2</sub> O output/man/shift, metric tons .....	—	.37	.55	.59	.74	.86

## Appendix X

INTERNAL ORGANIZATION OF THE I.C.I.

By H. J. Mitchell\*

Technically, I.C.I. is a holding company, that is, it owns the share capital either in whole or in part of various subsidiary and associated companies. In practice, however, it is primarily a manufacturing company owning branches at home and overseas. At the inception of the company the problem which faced the board was to devise a form of administration which, while providing elasticity and rapidity of decision, would ensure the adoption of a common policy throughout the entire company and at the same time prevent overlapping and wasteful duplication—in other words, a true amalgamation and not merely a financial one. We had to try to avoid the two extremes of complete centralization on the one hand or a loose financial merger on the other. . . .

The I.C.I. organization differs from many others in that its theory is that it is better from a psychological point of view for a man to be told what he may not do without higher authority, rather than to define what he may do. In other words, make clear to your people just how far they can act independently and that they are expected to go that length without bothering their chiefs, unless they really want advice.

At the top of the scheme of organization there is, of course, the board of the company, with the chairman at the head with fourteen other directors, of whom eight give their whole time to the service of the company. The whole-time directors form the

\* From *I.C.I. Mag.*, Jan. 1935, quoted by *Chem. Trade J.* 29, Jan. 11, 1935.

General Purposes Committee of the board, and three of them constitute the Finance Committee, together with the chairman and president. Next there is the Central Administration Committee, which has specific powers of decision conferred on it by the chairman. Important matters requiring decision are submitted through the medium of the Central Administration Committee, and if within its powers that committee decides the issue and reports to the General Purposes Committee—if not, it passes the matter up with its recommendation. A director of I.C.I. acts as chairman of the Central Administration Committee, the membership of which includes the chairmen in the eight operating groups and the heads of departments in Millbank. The “clearing house” activities of the Central Administration Committee make certain that no policy adopted by one unit can prejudice the interests of another. . . .

The manufacturing units are organized into eight operating groups, each with its defined field of activity, entitled for simple reference the Alkali Group, the Dyestuffs Group, the Explosives Group, the Fertilizers & Synthetic Products Group, the General Chemicals Group, the Leather Cloth Group, the Lime Group, and the Metals Group. The statutory or legal “board” of the companies of the groups is I.C.I. itself, and thus the final responsibility rests on the members of the I.C.I. board.

The responsibility for the day-to-day administration of each operating group rests with its chairman and his delegate board, made up of whole-time officials (both of the group itself and of head office) appointed by I.C.I. and vested with authority to take action within defined limits. Matters of major importance or of policy have to be submitted to head office. The coordination of policy in matters common to all groups is made effective by constant contact between the group heads, by head office representation on the delegate boards, and by the functions of the several head office departments, such as the Treasury, the Secretariat, Sales, Labor, etc.

The “Associated” companies, on the other hand, are administered by boards of directors, upon which I.C.I. is represented by some of the officials, who keep in close contact with the management and give general guidance, direction on I.C.I. policy, and all possible assistance in administration.

The overseas companies are directed and managed by local boards, and although I.C.I. does not exercise control it is kept cognisant by those boards of all matters affecting questions of major policy so that any possible conflict of interests is avoided. There is available to these companies the advice of all departments of I.C.I. which they may desire to consult, and this liaison contact rests primarily with the Central Sales Department, so that as far as possible a common home and foreign sales policy is pursued.

## Appendix XI

U. S. SULFURIC ACID STATISTICS <sup>a</sup>

Year	Production <sup>b</sup>			Imports		Exports	
	<i>firms</i>	<i>short tons</i>	<i>value</i>	<i>short tons</i>	<i>value</i>	<i>short tons</i>	<i>value</i>
1923.....	185	{ 4,344,698 6,555,517	{ \$38,274,540 57,750,000	11,754	\$198,083	4,122	\$169,161
1924.....	—	—	—	7,734	132,460	5,636	180,012
1925.....	177	{ 4,700,197 7,004,112	{ 38,230,284 56,540,000	18,191	241,515	3,769	151,819
1926.....	—	—	—	27,969	337,634	4,612	174,423
1927.....	181	{ 4,971,583 7,335,795	{ 42,885,573 63,161,000	17,434	198,306	3,756	166,339
1928.....	—	—	—	13,164	160,892	3,500	146,345
1929.....	170	{ 5,816,165 8,491,114	{ 45,573,245 65,869,000	8,104	97,414	3,480	141,829

<sup>a</sup> From official Govt. sources; <sup>b</sup> 50° Bé. basis, sales & total production, resp.

## Appendix XII

## U. S. PRODUCTION OF CONTACT AND CHAMBER SULFURIC ACID

(From *Census of Mfrs.*)

	1923	1925	1927	1929
Production, 50° Bé., short tons				
Contact .....	1,812,341	2,050,530	2,223,146	3,076,240
Chamber .....	4,743,000	4,953,582	5,112,649	5,414,874
% of total .....	27.6	29.2	30.3	36.2
Number of establishments				
Contact .....	34	37	37	42
Chamber .....	160	153	155	141
Both .....	—	13	11	13
Platinum in contact mass, troy oz...	36,650	30,348	31,462	37,512

## Appendix XIII

## DISTRIBUTION OF SULFURIC ACID CONSUMED IN U. S.\*

(From *Chem. Met. Eng.*, Ann. Rev.)

<i>Consuming Industries</i>	1923	1924	1925	1926
Fertilizers .....	2,070	1,800	1,975	1,850
Petroleum refining .....	1,200	1,300	1,453	1,510
Chemicals .....	1,000	1,000	1,096	1,250
Coal products .....	—	—	—	—
Iron & steel .....	700	600	729	740
Other metals .....	500	600	702	725
Textiles, paints, & pigments .....	310	300	315	320
Explosives .....	200	180	185	190
Miscellaneous .....	620	400	557	450
Totals .....	6,600	6,180	7,012	7,035

<i>Consuming Industries</i>	1927	1928	1929	1930
Fertilizers .....	1,925	2,300	2,418	2,477
Petroleum refining .....	1,325	1,350	1,570	1,420
Chemicals .....	725	745	890	820
Coal products .....	732	740	935	800
Iron & steel .....	685	670	800	660
Other metals .....	700	570	675	560
Paints & Pigments .....	210	205	225	200
Explosives .....	183	170	195	177
Rayon & cellulose film .....	—	105	150	145
Textiles .....	135	78	90	78
Miscellaneous .....	290	292	390	330
Totals .....	7,010	7,225	8,438	7,667

\* In 1,000 short tons, 50° Bé. basis.

## Appendix XIV

## THE FIRST CONTACT SULFURIC ACID PLANT

By George A. Whiting\*

The first contact sulfuric acid plant constructed in this country for use of the Selden vanadium mass was built for us at our Curtis Bay plant, by the Chemical Construction Co. in 1927, and started operation in November of that year. News of the construction of this plant and its proposed use of the Selden vanadium mass was instrumental in precipitating the patent suit wherein the General Chemical Co. charged the Selden Co. with infringement of the Slama-Wolf patent owned by the General Chemical Co.

The question really in issue at that time was whether the General Chemical Co. would be able to maintain the strong control of the contact sulfuric acid industry which it enjoyed and which was threatened by the construction of our plant. The feeling was so strong at that time that even after the Selden patent had been declared valid, suit was brought against the Standard Wholesale Phosphate & Acid Works by the General

\* To author, Feb. 28, 1946.

Chemical Co., charging that the vanadium catalyst supplied for this first plant, a 50-ton unit built in 1927, and the second and third plants, 80 and 120 tons respectively, built in 1929, did not conform to the specifications set forth in the Selden patent. This suit was defended by the Chemical Construction Co. in our behalf. Again satisfaction was denied to the General Chemical Co. and the Selden patent upheld.

This was a very interesting period, as we were actually being used as a "guinea pig" to determine whether the Badische and Slama-Wolf patents were to continue to dominate the field, or whether the vanadium catalyst developed by Selden, Monsanto, and Chemical Construction companies, but awaiting actual commercial demonstration, would be able to open the contact sulfuric acid manufacturing field to wide and diversified competition. We have always been proud of our small part in pioneering this venture and have had such satisfactory experiences that we now have five Chemico contact plants, the largest of which has a 300-ton per day capacity. The original 50-ton unit, which caused all the patent litigation, is still in operation and performing splendidly. Although the larger, newer units have greatly improved operating costs over the original design, the original 50-ton unit still runs at capacity and pays its way.

## Appendix XV

### SULFURIC ACID PLANTS IN U. S., 1929

[From *Chem. Met. Eng.* 37, 50, 172 (1930).]

#### *Chamber Plants: Total 204*

Acme Mfg. Co.: Wilmington, N. C.

American Agricultural Chemical Co.: Montgomery, Ala.; Los Angeles; Pensacola, Fla.; Savannah; Baltimore; N. Weymouth, Mass.; Detroit; Carteret & Chrome, N. J.; Buffalo; Wilmington & Columbia, N. C.; Cincinnati; Cleveland; Charleston & Columbia, S. C.; Alexandria, Va.

American Cyanamid Co.: Warners, N. J.

American Sheet & Tin Plate Co.: Vandergrift, Pa.

American Steel & Wire Co.: Donora, Pa.; Cleveland

American Zinc & Chemical Co.: Langeloth, Pa.

American Zinc, Lead & Smelting Co.: E. St. Louis; Hillsboro, Ill.

Anaconda Copper Mining Co.: Anaconda, Mont.

Anderson Fertilizer Works: Anderson, S. C.

Armour Fertilizer Works: Jacksonville, Fla.; Atlanta & Columbus, Ga.; Chicago Heights, Ill.; New Orleans; Carteret, N. J.; Greensboro & Wilmington, N. C.; Cincinnati & Sandusky, O.; Nashville, Tenn.; Houston, Tex.

Atlantic Chemical Co.: Lowell, Mass.

Avery Chemical Co.: Tewksbury, Mass.

Barbour Chemical Works: Melrose, Calif.

Barker Chemical Co.: Dunnellon, Fla.

Baugh Chemical Co.: Baltimore

Blackshear Mfg. Co.: Blackshear, Ga.

Calco Chemical Co.: Boundbrook, N. J.

Calumet & Arizona Mining Co.: Douglas, Ariz.

Caraleigh Phosphate & Fertilizer Works, Raleigh, N. C.

Central Chemical Co.: W. Hammond, Ill.

Cleveland-Cliffs Iron Co.: Marquette, Mich.

Cotton States Fertilizer Co.: Macon, Ga.

Davison Chemical Co.: Baltimore

Davison-Gulfport Fertilizer Co.: Gulfport, Miss.

Dixie Guano Co.: Laurinburg, N. C.

E. I. du Pont de Nemours & Co.: Du Pont, Wash.; Barksdale, Wis.

Ducktown Chemical & Iron Co.: Isabella, Tenn.

Eagle-Picher Zinc Co.: Hillsboro, Ill.

Empire State Fertilizer Co.: Athens, Ga.

Etiwan Fertilizer Co.: Charleston, S. C.

Fairmont Chemical Co.: Fairmont, W. Va.

Farmers' Fertilizer Co.: Montgomery, Ala.; Columbus, O.

Federal Chemical Co.: Columbus, O.; Nashville, Tenn.

Furman Fertilizer Works: East Point, Ga.

General Chemical Co.: Buffalo (2); Denver; Edgewater, N. J.

Georgia Fertilizer Co.: Valdosta, Ga.



- Grasselli Chemical Co.: Grasselli, Ind.; Grasselli, Paulsboro, & Newark, N. J.; Canton, Cleveland, Lockland, & Niles, O.; Beaver Falls, New Castle, & Philadelphia, Pa.
- Griffith & Boyd Co.: Baltimore.
- Hegeler Zinc Co.: Danville, Ill.
- Home Guano Co.: Dothan, Ala.; Columbus, Ga.
- Illinois Zinc Co.: Peru, Ill.
- International Agricultural Corp.: Columbus, Ga.; Tupelo, Miss.
- Jackson Fertilizer Co.: Jackson, Miss.
- Jarecki Chemical Co.: Cincinnati.
- Jefferson Fertilizer Co.: Bessemer, Ala.
- Kalbfleisch Corp.: Waterbury, Conn.; Elizabeth, N. J.; Erie, Pa.
- Lancaster Chemical Co.: Perryville, Md.; Lancaster, Pa.
- Laurel Oil & Fertilizer Co.: Laurel, Miss.
- Chas. Lennig & Co.: Philadelphia
- Lowell Fertilizer Co.: Lowell, Mass.
- McCabe Chemical Co.: Macon, Ga.; Charlotte, N. C.
- Mandeville Mills: Carrollton, Ga.
- Matthiessen & Hegeler Zinc Co.: La Salle, Ill.
- Maybank Fertilizer Co.: Charleston, S. C.
- Merchant's Feed & Phosphate Co.: Charlotte, N. C.
- Merchants' Fertilizer & Phosphate Co.: Charleston, S. C.
- Merck & Co.: Philadelphia
- Meridian Fertilizer Factory: Meridian & Hattiesburg, Miss.
- Merrimac Chemical Co.: Everett & Woburn, Mass.
- Monsanto Chemical Works: E. St. Louis & Monsanto, Ill.
- Morris Fertilizer Co.: Atlanta, Ga.
- Mountain Copper Co.: Martinez, Calif.
- Mutual Chemical Co.: Baltimore; Jersey City, N. J.
- Mutual Fertilizer Co.: Savannah
- Naugatuck Chemical Co.: Naugatuck, Conn.
- E. O. Painter Fertilizer Co.: Jacksonville, Fla.
- Pelham Phosphate Co.: Pelham, Ga.
- Pennsylvania Salt Mfg. Co.: Natrona & Philadelphia, Pa.
- Phosphate Mining Co.: Savannah
- Planters' Chemical & Oil Co.: Talladega, Ala.
- Planters' Fertilizer & Chemical Co.: New Orleans
- Planters' Fertilizer & Phosphate Co.: Charleston, S. C.
- Powers-Weightman-Rosengarten Co.: Philadelphia
- Raisin Monumental Co.: Baltimore
- Read Fertilizer Co.: Charleston, S. C.
- Read Phosphate Co.: Nashville, Tenn.
- Reliance Fertilizer Co.: Savannah
- Richmond Guano Co.: Richmond, Va.
- Roanoke Guano Co.: Roanoke, Ala.
- Robertson Chemical Corp.: Norfolk, Va.
- Robinson Bros. Co.: Brooklyn, N. Y.
- F. S. Royster Guano Co.: Birmingham, Ala.; Macon, Ga.; Baltimore; Columbia, S. C.; Norfolk, Va.
- St. Bernard Acid Works: St. Bernard, O.
- Savannah Guano Co.: Savannah
- Smith Agricultural Chemical Co.: Columbus, O.
- Southern Acid & Sulphur Co.: Augusta, Ark.
- Southern Fertilizer & Chemical Co.: Savannah
- Southern States Phosphate & Fertilizer Co.: Augusta, Ga.
- Southern Sulphur Oil Co.: Athens, Ga.
- Southern Sulphur Ore Co.: Columbus, Ga.
- Standard Chemical Co.: Troy, Ala.
- Standard Oil Co. (N. J.): Bayonne, N. J. (not operating)
- Standard Wholesale Phosphate & Acid Works: Baltimore
- Stauffer Chemical Co.: Los Angeles, San Francisco, & Stege, Calif.
- Steel Cities Chemical Co.: Ensley, Ala.
- Swift Fertilizer Co.: Atlanta, Ga.; New Orleans; Wilmington, N. C.
- Tennessee Chemical Co.: Albany, Ga.
- Tennessee Copper & Chemical Corp.: Copper Hill, Tenn.
- I. P. Thomas & Son Co.: Paulsboro, N. J. (not operating)
- Trout Co.: La Grange, Ga.
- F. W. Tunnell & Co.: Philadelphia
- Tupelo Agricultural Chemical Co.: Tupelo, Miss.
- Union Seed & Fertilizer Co.: Gretna, La.
- United Chemical Co.: Dallas, Tex.
- United Gas Improvement Co.: Pt. Breeze (Phila.)
- United Zinc Smelting Corp.: Moundsville, W. Va.
- Victor Chemical Works: Nashville, Tenn.
- Virginia-Carolina Chemical Co.: Birmingham, Dothan, Mobile, Opelika, & Selma, Ala.; Atlanta, Augusta, Columbus, Macon, Rome, & Savannah, Ga.; Shreve-

port, La.; Baltimore; Charlotte, Durham, Navassa, Selma, Wadesboro, Wilmington, & Winston-Salem, N. C.; Cincinnati & Sandusky, O.; Blacksburg, Charleston, Greenville, & Pon Pon, S. C.; Memphis, Tenn.; Lynchburg, Pinners Pt., Richmond, & Portsmouth, Va.  
 Wilson & Toomer Fertilizer Co.: Jacksonville, Fla.  
 York Chemical Works: York, Pa.

*Contact Plants: Total 62*

American Cyanamid Co.: Tampa, Fla.; Warners, N. J.  
 Apache Powder Co.: Douglas, Ariz.  
 Atlas Powder Co.: Atlas, Mo.; Hopatcong, N. J.; Tamaqua, Pa.  
 Calco Chemical Co.: Bound Brook, N. J.  
 Davison Chemical Co.: Baltimore  
 Detroit Chemical Works: Detroit  
 Dominguez Chemical Co.: Dominguez, Calif.  
 E. I. du Pont de Nemours & Co.: Mineral Springs, Ala.; Louviers, Colo. (not operating); Deepwater, N. J.; Du Pont, Wash.; Barksdale, Wis.  
 Ducktown Chemical & Iron Co.: Isabella, Tenn.  
 Eagle-Picher Zinc Co.: Hillsboro, Ill.  
 Eastman Kodak Co.: Rochester, N. Y.  
 General Chemical Co.: Bay Pt. & El Segundo, Calif.; Cleveland; Buffalo; Den-

ver; Claymont, Del.; S. Chicago; Edgewater, N. J.; Newell, Pa.; Pulaski, Va.  
 Grasselli Chemical Co.: Wurtland, Ky.; Ecorse, Mich.; Grasselli, Ind.; Grasselli, N. J.; Cleveland & Toledo, O.; Philadelphia  
 Gulf Refining Co.: Port Arthur, Tex.  
 Hercules Powder Co.: Pinole, Calif. (not operating); Kenvil & Parlin, N. J.; Emporium, Pa.; Bacchus, Utah  
 Louisiana Chemical Co.: Baton Rouge, La.  
 Merrimac Chemical Co.: Everett & Woburn, Mass.  
 Monsanto Chemical Works: Monsanto, Ill.  
 National Zinc Co.: Bartlesville, Okla.  
 National Zinc Ore Separating Co.: Cuba City, Wis.  
 Naval Proving Ground: Indian Head, Md.  
 New Jersey Zinc Co.: Depue, Ill.; Palmerston, Pa.  
 Ozark Chemical Co.: W. Tulsa, Okla.  
 Pennsylvania Salt Mfg. Co.: Natrona & Philadelphia, Pa.  
 Southern Acid & Sulphur Co.: Bossier City, La.; Port Arthur, Tex.  
 Standard Wholesale Phosphate & Acid Works: Baltimore  
 Stauffer Chemical Co.: Los Angeles & Stege, Calif.; Hammond, Ind.  
 Texas Chemical Co.: Fort Worth & Houston, Tex.  
 Trojan Powder Co.: Seiple, Pa.

## Appendix XVI

### U. S. SULFUR STATISTICS (long tons)

(From *Min. Res.*)

Year (fiscal)	Production	Total Shipments	Imports <sup>a</sup>	Exports <sup>b</sup>	Apparent Consumption <sup>c</sup>
1923.....	2,036,097	1,618,841	465	472,525	1,146,781
1924.....	1,220,561	1,537,345	1,005	482,114	1,056,236
1925.....	1,409,262	1,585,003	100	629,401	1,228,702
1926.....	1,890,027	2,072,657	48	576,966	1,495,739
1927.....	2,111,618	2,072,109	3,384	789,274	1,286,219
1928.....	1,981,873	2,082,924	4,787	685,051	1,402,660
1929.....	2,362,389	2,437,238	1,163	855,183	1,583,218

<sup>a</sup> All grades of S, including refined & ore; <sup>b</sup> Crude S, although U. S. exports 10,000-20,000 long tons of refined grades per yr.; <sup>c</sup> Total shipments less exports, plus imports, but actual consumption varies with consumers' inventories & S in transit.

## Appendix XVII

SULFUR CONSUMPTION IN U. S. FROM VARIOUS SOURCES (1,000 long tons) <sup>a</sup>  
(From Haynes, *Stone That Burns*, p. 314.)

Year	Apparent Sulfur Consumption Brimstone <sup>b</sup>	Pyrites Production <sup>c</sup>	Pyrites Imports <sup>d</sup>	H <sub>2</sub> SO <sub>4</sub> Copper & Zinc Smelters <sup>e</sup>	Total Sulfur
1923.....	1,146	78	119	197	1,540
1924.....	1,055	69	111	203	1,438
1925.....	1,229	77	124	235	1,665
1926.....	1,496	87	165	236	1,984
1927.....	1,283	116	113	222	1,734
1928.....	1,398	113	206	234	1,951
1929.....	1,582	120	231	243	2,176

SULFUR CONSUMPTION IN CHEMICAL INDUSTRY (1,000 long tons)  
(*Chem. Met. Eng. Estimates.*)

<i>Consuming Industries</i>	1927	1928	1929	<i>Consuming Industries</i>	1927	1928	1929
Heavy chemicals .....	490	520	560	Pulp & paper .....	260	250	265
Fine chemicals .....	13	14	15	Rubber .....	25	40	43
Electrochemicals .....	20	21	23	Food products .....	3	5	5
Dyes & coal-tar products	40	42	47	Paint & varnish .....	1	5	5
Fertilizers & insecticides	275	345	415	Explosives .....	65	60	67
Petroleum products ...	1	1	1	Miscellaneous .....	34	123	136
Rayon & textiles .....	1	—	—	Totals .....	1,228	1,426	1,582

<sup>a</sup> No allowance for changes in consumers' stocks, S from H<sub>2</sub>S & acid sludge excluded, pyrites & smelter gas in equiv. S; <sup>b</sup> Shipments plus imports less exports, Bur. Mines; <sup>c</sup> Bur. Mines; <sup>d</sup> Dept. Com., S calc. at 45%; <sup>e</sup> 1924-29 Bur. Mines, 1923 estimated, 1924-29 adjusted for flotation conc. now reported as pyrites.

## Appendix XVIII

PYRITES IN U. S. (long tons)  
(From *Min. Res.*)

Year	Production	Imports	Apparent Consumption
1923.....	190,635	263,695	454,330
1924.....	167,914	246,737	414,651
1925.....	193,642	276,385	470,027
1926.....	226,933	366,151	593,084
1927.....	302,826	250,794	553,620
1928.....	312,815	457,123	769,938
1929.....	333,465	514,336	847,801

## Appendix XIX

U. S. PRODUCTION AND DISTRIBUTION OF AMMONIA PRODUCTS <sup>a</sup>

(Chem. Met. Eng. Estimates.)

<i>Production</i>	<i>1923</i>	<i>1924</i>	<i>1925</i>	<i>1926</i>	<i>1927</i>	<i>1928</i>
Coke works .....	115,000	109,000	128,000	142,300	147,000	164,500
Gasworks .....	5,500	5,500	5,500	6,400	6,200	6,500
Air-fixation .....	3,000	3,400	11,000	12,800	18,200	27,000
Bone distillation, etc....	200	200	200	200	200	200
Total .....	<u>113,700</u>	<u>118,200</u>	<u>294,700</u>	<u>161,700</u>	<u>172,100</u>	<u>198,200</u>
<i>Consuming industries</i>						
Fertilizers .....	42,000	48,000	54,000	57,200	57,500	328,300
Anhydrous ammonia ..	13,500	13,500	15,000	15,000 <sup>b</sup>	16,500 <sup>b</sup>	14,000 <sup>c</sup>
Aqueous ammonia .....	18,600	22,000	24,000	25,000	24,000	6,000
Explosives .....	7,200	7,200	7,500	8,200	8,200	22,500 <sup>d</sup>
Miscellaneous ammoni- um salts & nitrates ...	5,000	5,000	5,000	5,300	5,500	15,000 <sup>e</sup>
Rayon, soda ash, cy- anides, etc. ....	—	—	—	7,000	7,000	13,500
Nitric acid .....	—	—	—	1,200	2,500	43,000 <sup>f</sup>
Imports .....	—	—	—	199,400 <sup>g</sup>	191,400 <sup>g</sup>	269,000 <sup>g</sup>
Exports .....	—	—	—	45,800 <sup>h</sup>	37,100 <sup>h</sup>	35,400 <sup>h</sup>
Apparent U. S. Con- sumption .....	—	—	—	315,300	326,400	431,800

<sup>a</sup> Quantities in net tons of N; <sup>b</sup> Used mainly as refrigerant; <sup>c</sup> For refrigeration; <sup>d</sup> Excluding Chile nitrate & ammonia requirements of HNO<sub>3</sub> manufacture; <sup>e</sup> Including 11,000 tons Chile nitrate; <sup>f</sup> Including acid requirements for chamber acid plants; <sup>g</sup> Including ammonium sulfate, ammonium sulfate-nitrate, cyanamide, calcium nitrate, Chile nitrate, cyanides, miscellaneous ammonium & nitrate compounds, nitrogenous fertilizer mixtures (est.); <sup>h</sup> Including ammonium sulfate, sodium nitrate, anhydrous ammonia, other N compounds.

## Appendix XX

U. S. PRODUCTION AND IMPORTS OF NITRIC ACID <sup>a</sup>

Year	Production <sup>b</sup>			Imports <sup>c</sup>	
	<i>firms</i>	<i>short tons</i>	<i>value</i>	<i>pounds</i>	<i>value</i>
1923.....	55	21,759 113,116	\$2,741,370 —	7,460	\$ 491
1924.....	—	—	—	215	30
1925.....	53	26,852 119,652	3,559,695 —	2,702	427
1926.....	—	—	—	1,809	82
1927.....	50	28,706 121,991	3,559,436 —	36,508	1,490
1928.....	—	—	—	379,048	15,838
1929.....	48	32,961 143,454	3,494,577 —	228,585	9,429

<sup>a</sup> From official Govt. sources; <sup>b</sup> Sales & total production, resp., of all strengths, 1923-27, 100% basis, 1929; <sup>c</sup> No exports reported for 1923-30.

## Appendix XXI

## PRODUCTION OF PHOSPHORIC ACID AND PHOSPHATES IN U. S.

(From *Census of Mfrs.*)

	1923	1925	1927	1929
<i>Phosphoric Acid</i>				
No. firms .....	11	7	6	9
Pounds .....	12,829,361	21,330,215	22,397,366	34,673,982
Value .....	\$955,194	\$1,488,701	\$1,681,504	\$2,073,066
<i>Phosphate: Monocalcium</i>				
No. firms .....		9	7	
Tons .....		34,725	33,636	
Value .....	14	\$4,298,152	\$4,867,979	8
<i>Di- &amp; Tricalcium</i>	38,751			38,139
No. firms .....	\$4,393,119	4	4	\$5,557,454
Tons .....		1,039	367	
Value .....		\$154,563	\$46,107	
<i>Sodium, Mono-, Di-, &amp; Pyrosodium</i>	14	13	11	14
Tons .....	10,375	30,561	32,950	63,349
Value .....	\$1,215,922	\$2,467,387	\$2,460,656	\$3,955,723
<i>Trisodium</i>				
Tons .....	26,224	48,783	63,531	82,045
Value .....	\$1,955,632	\$3,288,101	\$4,524,595	\$5,008,815

## Appendix XXII

U. S. PHOSPHATE ROCK STATISTICS <sup>a</sup>

Year	Production		Imports		Exports	
	<i>long tons</i>	<i>value</i>	<i>long tons</i>	<i>value</i>	<i>long tons</i>	<i>value</i>
1923.....	3,006,706	\$11,576,049	6,725	\$ 92,263	824,904	\$5,752,507
1924.....	2,867,789	10,252,083	16,098	181,515	807,751	5,023,159
1925.....	3,481,819	11,545,678	2,735	37,932	856,876	5,570,446
1926.....	3,209,976	10,893,800	17,378	192,611	737,934	4,351,461
1927.....	3,170,699	11,253,352	28,195	292,871	918,211	4,725,562
1928.....	3,501,406	12,443,179	45,812	431,238	898,764	4,452,101
1929.....	3,760,855	13,153,259	44,899	469,171	1,142,746	5,386,919

## Utilization (long tons)

	1923	1924	1925	1926
Application to soil .....	10,548	14,320	31,999	29,902
Chemicals .....	214,691	107,901	129,955	149,072
Blast-furnace products ...	26,531	36,636	25,801	23,231
Stock feeds .....	—	2,938	2,605	4,911
Superphosphate <sup>b</sup> .....	1,934,110	1,903,319	—	2,268,275
Miscellaneous .....	—	—	4,000	3,000

	1927	1928	1929	1930
Application to soil .....	32,957	42,145	61,224	41,593
Chemicals .....	245,385	205,630	321,851	281,805
Stock feeds .....	4,297	4,780	4,791	4,478
Superphosphate <sup>b</sup> .....	1,997,979	2,380,791	2,262,239	2,367,787
Miscellaneous .....	—	15,108	12,903	39,929

<sup>a</sup> From official Govt. sources, <sup>b</sup> Estimated production: 1923—3,720,000 long tons, 1924—3,664,000, 1925—4,659,000, 1926—4,367,000, 1927—3,847,000, 1928—4,592,000, 1929—4,355,000, 1930—4,559,000.

## Appendix XXIII

## LIST OF CONSUMERS OF PHOSPHATE ROCK BY USES, 1928

(From *Min. Res.*)*Dicalcium phosphate fertilizers:* Myles Salt Co., Ltd., New Orleans.*Ferrophosphorus:* Ohio Ferro-Alloys Corp., Canton, O.; Oldbury Electro-Chemical Co., Niagara Falls; Southern Manganese Corp., Birmingham, Ala.; Tennessee Products Corp., Nashville, Tenn.; Victor Chemical Works, Chicago; Warner Iron Co., Nashville, Tenn.*Iron & steel:* American Rolling Mill Co., Middletown, O.; Antrim Iron Co., Grand Rapids, Mich.; Bethlehem Steel Corp., Bethlehem, Pa.; E. & G. Brooke Iron Co., Birdsboro, Pa.; Cleveland-Cliffs Iron Co., Cleveland; Colonial Iron Co., N.Y.C.; Columbia Steel Corp., San Francisco; Corrigan, McKinney Steel Co., Cleveland; Delaware River Steel Co., Chester, Pa.; Delta Chemical & Iron Co., Wells, Mich.; Hamilton Coke & Iron Co., Hamilton, O.; Hanna Furnace Co., Cleveland; Inland Steel Co., Chicago; International Harvester Co., Chicago; Jackson Iron & Steel Co., Jackson, O.; Marting Iron & Steel Co., Ironton, O.; Perry Iron Co., Cleveland; Pulaski Iron Co., Pulaski, Va.; Reliance Coke & Furnace Co., Pittsburgh; St. Louis Gas & Coke Corp., Granite City, Ill.; Shengango Furnace Co., Pittsburgh; Sloss-Sheffield Steel & Iron Co., Birmingham, Ala.; Superior Steel & Malleable Castings Co., Benton Harbor, Mich.; Toledo Furnace Co., Cleveland; Warren Foundry & Pipe Corp., Wharton, N. J.; Alan Wood Iron & Steel Co., Philadelphia; Youngstown Sheet & Tube Co., Youngstown, O.; Zenith Furnace Co., West Duluth, Minn.*Phosphates:* American Cyanamid Co., N.Y.C. (monoammonium; di- & trisodium); Anaconda Copper Mining Co., Anaconda, Mont. (ammonium); Blockson Chemical Co., Joliet, Ill. (ammonium; di- & trisodium); Bowker Chemical Co., N.Y.C. (di- & trisodium); Calumet Chemical Co., Joliet, Ill. (mono- & dicalcium); Federal Phosphorus Co., Birmingham, Ala. (mono- & diammonium; mono-, di-, tri-, & acid sodium; mono-, di-, & tricalcium); General Chemical Co., N.Y.C. (di- & trisodium); Grasselli Chemical Co., Cleveland (di- & trisodium); International Agricultural Corp., N.Y.C. (ammonium; di- & trisodium); Phosphate Products Corp., Richmond, Va. (ammonium; calcium acid; sodium; pyro- & trisodium); Rumford Chemical Works, Rumford, R. I. (mono-, di-, & tricalcium); Victor Chemical Works, Chicago (mono- & diammonium; mono-, di-, & tricalcium; mono-, di-, tri-, & acid pyrosodium); Virginia-Carolina Chemical Co., Richmond, Va. (monocalcium); Warner Chemical Co., N.Y.C. (mono-, di-, & trisodium); Wilckes-Martin-Wilckes Co., N.Y.C. (mono-, di-, & sodium ammonium; mono-, di-, & tricalcium; potassium).*Phosphoric acid:* Anaconda Copper Mining Co., Anaconda, Mont.; Bowker Chemical Co., N.Y.C.; Federal Phosphorus Co., Birmingham, Ala.; International Agricultural Corp., N.Y.C.; Phosphate Products Corp., Richmond, Va.; Provident Chemical Works, St. Louis; Rumford Chemical Works, Rumford, R. I.; Victor Chemical Works, Chicago; Virginia-Carolina Chemical Co., Richmond, Va.; Warner Chemical Co., N.Y.C.; Wilckes-Martin-Wilckes Co., N.Y.C.*Phosphorus:* Oldbury Electro-Chemical Co., Niagara Falls.*Stock & poultry feed:* Moorman Mfg. Co., Quincy, Ill.; Myles Salt Co., Ltd., New Orleans; Vitamineral Products Co., Peoria, Ill.*Superphosphate:* Acme Mfg. Co., Wilmington, N. C.; Alabama Chemical Co., Montgomery, Ala.; American Agricultural Chemical Co., N.Y.C.; Anaconda Copper Mining Co., Chicago; Anderson Fertilizer Works, Anderson, S. C.; Arkansas Fertilizer Co., Little Rock, Ark.; Armour Fertilizer Works, Chicago.*Barker Chemical Co., Savannah; Baugh & Sons Co., Philadelphia; Baugh Chemical Co., Baltimore; Blackshear Mfg. Co., Blackshear, Ga.; D. Brown Guano Co., Albany, Ga.**Calumet Fertilizer Corp., N.Y.C.; Capital City Acid Phosphate Co., Little Rock, Ark.;*

Capital Fertilizer Co., Montgomery, Ala.; Caraleigh Phosphate & Fertilizer Works, Raleigh, N. C.; Catawba Fertilizer Co., Lancaster, S. C.; Central Chemical Co., Hagerstown, Md.; Chickamauga Fertilizer Works, Atlanta; Columbus Fertilizer Co., Columbus, Ga.; Congaree Fertilizer Co., Columbia, S. C.; Contentnea Guano Co., Wilson, N. C.; Cotton States Fertilizer Co., Macon, Ga.

Darling & Co., Chicago; Davison Chemical Co., Baltimore; Davison-Pick Fertilizers, Inc., New Orleans; Diamond Fertilizer Co., Sandusky, O.; Dixie Guano Co., Laurinburg, N. C.; Dockwiler & Kingsbury Co., Indianapolis.

Empire State Chemical Co., Athens, Ga.; Etiwan Fertilizer Co., Charleston, S. C.

Farmers' Fertilizer Co., Columbus, O.; Farmers' Guano Co., Norfolk, Va.; Federal Chemical Co., Louisville, Ky.; Furman Fertilizer Works, Atlanta.

Georgia Fertilizer Co., Valdosta, Ga.; Grasselli Chemical Co., Birmingham, Ala.; Griffith & Boyd Co., Baltimore; Groves Fertilizer Works, Cincinnati; Gulfport Fertilizer Co., Gulfport, Miss.

M. Hamm Co., Wash. Court House, O.; Hartsville Fertilizer Co., Hartsville, S. C.; Home Guano Co., Dothan, Ala.

International Agricultural Corp., N.Y.C.; Jackson Fertilizer Co., Jackson, Miss.; Jarecki Chemical Co., Chicago; N. B. Josey Guano Co., Wilmington, N. C.

King Chemical Co., Bound Brook, N. J.; Knoxville Fertilizer Co., Knoxville, Tenn.

Laurel Oil & Fertilizer Co., Laurel, Miss.; Lowell Fertilizer Co., Boston.

McCabe Fertilizer Co., Charleston, S. C.; Mandeville Mills, Carrollton, Ga.; Maybank Fertilizer Co., Charleston, S. C.; Merchants' Fertilizer & Phosphate Co., Charleston, S. C.; Meridian Fertilizer Factory, Meridian, Miss.; Miller Fertilizer Co., Baltimore; Montezuma Fertilizer Co., Montezuma, Ga.; Morris Fertilizer Co., Chicago; Mountain Copper Co., Ltd., San Francisco; Mutual Fertilizer Co., Savannah.

G. Ober & Sons Co., Baltimore.

Pacific Guano & Fertilizer Co., San Francisco; Pelham Phosphate Co., Pelham, Ga.; Pennsylvania Salt Mfg. Co., Philadelphia; Piedmont-Mt. Airy Guano Co., Baltimore; Pittsburgh Provision & Packing Co., Pittsburgh; Planters' Chemical & Oil Co., Talladega, Ala.; Planters' Fertilizer & Phosphate Co., Charleston, S. C.; Porter Fertilizer Works, Atlanta; Powhatan Fertilizer Co., Greenville, S. C.

F. Rauh & Sons Fertilizer Co., Indianapolis; Read Phosphate Co., Savannah; Reading Bone Fertilizer Co., Reading, Pa.; Redd Chemical & Nitrate Co., Birmingham, Ala.; Reliance Fertilizer Co., Savannah; Richmond Guano Co., Richmond, Va.; Roanoke Guano Co., Roanoke, Ala.; Robertson Chemical Corp., Norfolk, Va.; F. S. Royster Guano Co., Norfolk, Va.

Shreveport Fertilizer Works, Shreveport, La.; Smith Agricultural Chemical Co., Columbus, O.; Southern Agricultural Chemical Corp., N.Y.C.; Southern Fertilizer & Chemical Co., Savannah; Southern States Phosphate & Fertilizer Co., Augusta, Ga.; Standard Chemical Co., Troy, Ala.; Standard Fertilizer Co., Gainesville, Fla.; Standard Wholesale Phosphate & Acid Works, Inc., Baltimore; Summers Fertilizer Co., Baltimore; Swift & Co., Chicago.

Talladega Fertilizer Mfg. Co., Talladega, Ala.; Tennessee Chemical Co., Nashville, Tenn.; I. P. Thomas & Son Co., Philadelphia; F. W. Tunnell & Co., Philadelphia.

U. S. Phosphoric Products Corp., Tampa, Fla.

Virginia-Carolina Chemical Co., Richmond, Va.

Welch Chemical Co., Columbus, O.; Wilson & Toomer Fertilizer Co., Jacksonville, Fla.; Wuichet Fertilizer Co., Dayton, O.; Wulbern Fertilizer Co., Charleston, S. C.

York Chemical Works, York, Pa.



## Appendix XXIV

U. S. PRODUCTION OF ALKALIES <sup>a</sup>  
(From *Census of Mfrs.*)

	1923	1925	1927	1929 <sup>b</sup>
<i>Caustic Soda</i>				
No. firms .....	23	22	23	—
Total production, tons.....	436,619	497,261	587,514	761,792
Made & consumed .....	5,658	10,116	26,112	37,118
Sales .....	430,961	487,145	561,402	724,674
Value .....	\$25,056,547	\$27,392,352	\$29,193,003	\$36,089,264
Lime-soda process				
No. firms .....	6	6	6	6
Tons .....	314,195	355,783	397,943	524,985
Electrolytic process				
No. firms .....	17	16	17	20
Tons .....	122,424	141,478	163,459	236,807
Repacked caustic (bulk)				
No. firms .....	12	12	6	6
Tons .....	32,828	26,687	21,104	17,474
Value .....	\$5,034,336	\$4,414,836	\$4,128,433	\$3,611,573
<i>Sal Soda</i>				
No. firms .....	26	29	21	19
Tons .....	68,802	63,619	55,220	57,850
Value .....	\$1,690,084	\$1,332,071	\$1,370,811	\$1,522,895
<i>Soda Ash</i>				
No. firms .....	14	12	12	14
Total production, tons .....	1,707,987	1,907,791	2,037,808	2,682,216
Made & consumed .....	449,207	539,131	571,429	868,360
Sales .....	1,258,780	1,368,660	1,466,379	1,813,856
Value .....	\$32,427,166	\$32,243,941	\$29,939,291	\$34,648,657
Ammonia-soda process				
No. firms .....	6	6	6	6
Total production .....	1,674,234	1,850,013	1,974,157	2,586,304
Sales .....	1,225,027	1,310,882	1,402,728	1,717,944
Value .....	\$31,413,210	\$30,914,558	\$28,645,404	\$32,540,942
Natural & electrolytic				
No. firms .....	8	6	6	8
Tons .....	33,758	57,778	63,651	95,912
Value .....	\$1,342,182	\$1,329,383	\$1,293,887	\$2,107,715
<i>Sodium Bicarbonate, Refined</i>				
No. firms .....	7	6	6	5
Tons .....	145,316	123,472	121,449	140,234
Value .....	\$3,738,129	\$3,651,848	\$3,647,446	\$4,062,074

<sup>a</sup> For imports & exports, see Appendix IV-V; <sup>b</sup> 3 firms produced 7,191 tons KOH, value \$637,977; <sup>c</sup> Excluding caustic made & consumed in wood pulp & textile industries.

## Appendix XXV

## DISTRIBUTION OF CAUSTIC SODA CONSUMED IN U. S. (1,000 short tons)

(Chem. Met. Eng. Estimates.)

<i>Consuming Industries</i>	1923	1924	1925	1926	1927	1928	1929
Soap .....	105	100	112	100	90	97	108
Chemicals .....	70	60	75	85	80	82.5	135
Petroleum refining .....	40	50	57	75	82.5	98	134
Rayon .....	40	35	49.5	60	65	82	111
Lye .....	55	53	57	40	35	32	25
Textiles .....	40	34	36	38	42.5	37.5	42
Rubber reclaiming .....	8	7	17	30	31	35	40
Vegetable oils .....	12	11	14.5	10	12	11	11
Pulp & paper .....	3	5	9	35	33	33	45
Storage batteries .....	2	3	5	5	—	—	—
Miscellaneous .....	4	4	15	17	33	31	48
Exports .....	57	46	50	52	50	59	60
Totals .....	436	408	497	547	554	598	759

## Appendix XXVI

## DISTRIBUTION OF SODA ASH CONSUMED IN U. S. (1,000 short tons)

(Chem. Met. Eng. Estimates.)

<i>Consuming Industries</i>	1923	1924	1925	1926	1927	1928	1929
Glassworks .....	—	535	585	665	604	620	672
Soap .....	86	150	200	200	205	210	213
Chemicals .....	50	160	180	200	200	225	335
Cleanders & modified sodas....	55 <sup>a</sup>	100	120	125	125	130	125
Pulp & paper .....	—	60	75	80	85	100	110
Water softeners .....	—	60	70	72	65	63	60
Petroleum refining .....	25	35	40	25	27	23	18
Textiles .....	40	30	35	36	38	36	40
Miscellaneous .....	34 <sup>b</sup>	46	50	70	45	45	47
Exports .....	60	14	16	20	21	30	40
Totals .....	350	1,190	1,371	1,493	1,415	1,482	1,660

<sup>a</sup> Lye; <sup>b</sup> 12,000 tons for vegetable oil refining, 8,000 for rubber working.

## Appendix XXVII

## ALKALI PRODUCERS IN U. S., 1929

[From *Chem. Met. Eng.* 37, 5 (1930).]

*Ammonia-soda alkali plants:* Columbia Chemical Co., Barberton, O.; Diamond Alkali Co., Painesville, O.; Mathieson Alkali Works, Saltville, Va.; Michigan Alkali Works, Wyandotte, Mich.; Solvay Process Co., Syracuse, N. Y., Detroit, Hutchinson, Kan. (not operating).

*Electrolytic alkali plants (commercial)*: Belle Alkali Co., Belle, W. Va.; Diamond Alkali Co., Painesville, O.; Dow Chemical Co., Midland, Mich.; E. I. du Pont de Nemours & Co., Deepwater Point, N. J.; Great Western Electro-Chemical Co., Pittsburg, Calif.; Gulf Refining Co., Port Arthur, Tex.; Hooker Electrochemical Co., Niagara Falls, Tacoma, Wash.; Isco Chemical Co., Niagara Falls; Mathieson Alkali Works, Niagara Falls, Providence, R. I.; Monsanto Chemical Works, E. St. Louis, Nitro, W. Va.; Niagara Alkali Co., Niagara Falls; Niagara Smelting Corp., Niagara Falls; Pennsylvania Salt Mfg. Co., Wyandotte & Menominee, Mich., Tacoma, Wash.; Solvay Process Co., Syracuse, N. Y.; Vulcan Detinning Co., Pittsburgh; Westvaco Chlorine Products Corp., S. Charleston, W. Va.

*Electrolytic alkali plants (pulp & paper mills)*: D. M. Bare Paper Co., Roaring Springs, Pa.; Brown Co., Berlin, N. H.; Champion Fibre Co., Canton, N. C.; Dill & Collins Co., Philadelphia; Eastern Mfg. Co., S. Brewer, Me.; Jessup & Moore Paper Co., Wilmington, Del., Elkton, Md.; Kimberly-Clark Co., Kimberly, Wis.; Miami Paper Co., Carrollton, O.; New York & Pennsylvania Paper Co., Johnsonburg, Pa.; Oxford Paper Co., Rumford, Me.; Penobscot Chemical Fibre Co., Gt. Works, Me.; S. D. Warren & Co., Cumberland, Me.; West Virginia Pulp & Paper Co., Mechanicville, N. Y., Covington, Va., Luke, Md., Tyrone, Pa.

*Natural alkali plants*: Clark Chemical Co., Lone Pine, Calif.; Inyo Chemical Co., Lone Pine, Calif.; Kuhnert Syndicate, Bartlett, Calif.; Natural Soda Products Co., Keeler, Calif.; West End Chemical Co., West End, Calif.

## Appendix XXVIII

### U. S. PRODUCTION OF SODIUM SULFATES<sup>a</sup>

(From Census of Mfrs.)

	1923	1925	1927	1929
<i>Glauber's Salt</i>				
No. firms .....	21	22	20	20
Tons .....	66,192	57,622	53,420	61,953
Value .....	\$1,521,095	\$1,265,260	\$1,081,980	\$1,112,269
<i>Niter Cake</i>				
No. firms .....	45	42	53	46
Total production, tons ..	154,087	124,296	153,615	111,522
Made & consumed .....	24,640	22,700	33,109	28,839
Sales .....	129,447	101,596	120,506	82,683
Value .....	\$587,897	\$400,598	\$625,049	\$1,023,136
<i>Salt Cake</i>				
No. firms .....	34	38	34	28
Total production, tons ..	187,064	189,293	208,565	206,612
Made & consumed .....	46,047	48,450	33,573	36,436
Sales .....	141,017	140,843	174,992	170,176
Value .....	\$2,972,013	\$2,339,002	\$2,786,818	\$2,014,838
<i>Sodium Sulfate, Natural<sup>b</sup></i>				
Total production, tons ..	10,080	9,940	23,080	7,540
Value .....	\$100,000	\$84,380	\$168,882	\$41,199

<sup>a</sup> Production of refined anhydrous salt amounted to 3,183 tons in 1923, 2,100 in 1925, 2,688 in 1927; <sup>b</sup> Salt cake plus Glauber's salt, figs. from *Min. Ind.* 1930, 557.

## Appendix XXIX

## DOMESTIC BAUXITE CONSUMED BY VARIOUS INDUSTRIES (long tons)

(From *Min. Ind.* 1929.)

Year	Aluminum	Chemical	Abrasive	Cement & Refractory	Total Tons	Total Value
1923.....	380,518	68,872	72,830	470	522,690	\$3,156,610
1924.....	225,780	54,870	66,400	520	347,570	2,137,990
1925.....	173,040	67,420	73,720	260	316,540	1,988,250
1926.....	241,850	77,960	72,210	230	392,250	2,415,200
1927.....	186,490	62,410	71,790	250	320,940	1,988,780
1928.....	218,398	83,992	72,931	105	375,426	2,273,898
1929.....	172,807	86,419	99,925	6,626	365,777	2,265,638

## PRODUCERS AND CONSUMERS OF BAUXITE, 1929 \*

(From *Min. Res.* 1929, I.)

Aluminum Ore Co., E. St. Louis; Armour Fertilizer Works, Cincinnati; Atlas Portland Cement Co., N.Y.C.; Bureau of Water Supply, Baltimore; Calumet Chemical Co., Joliet, Ill.; Carborundum Co., Niagara Falls; Central Chemical Co., Kokomo, Ind.; City of Columbus Purification Works, Columbus, O.; *Wm. J. Crouch Mining Co., Adairsville, Ga.; Dixie Bauxite Co., Sweet Home, Ark.; Exolon Co., Bladell, N. Y.; General Abrasive Co., Niagara Falls; General Chemical Co., N.Y.C.; General Refractories Co., N.Y.C.; Grasselli Chemical Co., Cleveland; Gulf Refining Co., Pittsburgh; Harbison-Walker Refractories Co., Pittsburgh; Kalbfleisch Corp., N.Y.C.; Laclede-Christy Clay Products Co., St. Louis; Chas. Lennig & Co., Philadelphia; Massillon Stone & Fire Brick Co., Massillon, O.; Merrimac Chemical Co., Boston; Metropolitan Utilities District, Omaha, Nebr.; Norton Co., Worcester, Mass., Niagara Falls; Passaic Consolidated Water Co., Paterson, N. J.; Pennsylvania Salt Mfg. Co., Philadelphia; *Republic Mining & Mfg. Co., N.Y.C.; Sacramento Filtration Works, Sacramento, Calif.; Stauffer Chemical Co., San Francisco; Superior Bauxite Co., Joliet, Ill.; Superior Chemical Co., Joliet, Ill.; Water Dept. of Kansas City, Mo.; Welch Chemical Co., Columbus, O.**

\* Producers italicized.

## Appendix XXX

U. S. PRODUCTION OF BARIUM SALTS <sup>a</sup>(From *Census of Mfrs.*)

	1923	1925	1927	1929
<i>Barium Carbonate</i>				
No. firms .....	4	4	4	7
Pounds .....	13,979,766	10,815,491	15,558,434	22,351,172
Value .....	\$484,138	\$300,468	\$463,591	\$648,617
<i>Chloride</i>				
No. firms .....	6	4	4	—
Pounds .....	7,294,361	7,923,187	6,668,043	—
Value .....	\$302,815	\$253,357	\$201,453	( <sup>b</sup> )

<sup>a</sup> For imports of carbonate (crude, precip.), chloride, dioxide, hydroxide, nitrate, & sulfate, see Appendix III; <sup>b</sup> Included in "Others."

U. S. PRODUCTION OF BARIUM SALTS (*Continued*)

	1923	1925	1927	1929
<i>Barium Sulfate (Blanc fixe)</i>				
No. firms .....	15	13	13	12
Total production, pounds.	21,661,123	26,089,696	30,061,944	—
Made & consumed .....	11,088,400	8,598,139	11,771,654	—
Sales .....	10,572,723	17,491,557	18,290,290	26,049,893
Value .....	\$351,819	\$621,807	\$565,822	\$958,446
<i>Others (Dioxide, Sulfide, etc.)</i>				
Value .....	\$216,484	\$322,428	\$376,264	\$626,900

## Appendix XXXI

U. S. CONSUMPTION OF CRUDE BARYTES IN BARIUM PRODUCTS <sup>a</sup>(From *Min. Res.* 1929, II, 210.)

Year	Barium Chemicals	Ground Barytes	Lithopone	Total
1923.....	34,327	47,713	128,547	210,587
1924.....	33,181	42,855	137,127	213,163
1925.....	29,141	56,851	146,693	232,685
1926.....	33,119	69,048	167,889	281,056
1927.....	34,280	73,119	222,791	330,190
1928.....	48,289	74,814	211,592	334,695
1929.....	52,448	58,770	223,188	334,406

PRODUCERS OF BARIUM PRODUCTS, 1929 <sup>b</sup>(From *Min. Res.* 1929, II, 217.)

*Barium chemicals*<sup>c</sup>: Alton Barium Products Co., Alton, Ill.; Barium Mining Corp., Charleston, W. Va.; Barium Products, Ltd., Modesto, Calif.; Barium Reduction Corp., Charleston, W. Va.; Chicago Copper & Chemical Co., Blue Is., Ill.; Grasselli Chemical Co., Philadelphia; Great Western Sugar Co., Johnstown, Colo.; Oakland Chemical Co., N.Y.C.; Titanium Pigment Co., St. Louis.

*Ground barytes*: Chemical & Pigment Co., Oakland, Calif.; Clinchfield Sand & Feldspar Co., Kings Creek, S. C.; C. P. DeLore Co., St. Louis; Flynt Silica & Spar Co., Los Angeles; Los Angeles Chemical Co., South Gate, Calif.; National Pigments & Chemical Co., St. Louis; Thompson, Weinman & Co., Cartersville, Ga.

*Lithopone*: Chemical & Pigment Co., Oakland, Calif., Collinsville, Ill., St. Helena, Md.; Eagle-Picher Lead Co., Argo, Ill.; Grasselli Chemical Co., Grasselli & Newark, N. J., Philadelphia; Krebs Pigment & Chemical Co., Newport, Del.; Mineral Point Zinc Co., Depue, Ill.; New Jersey Zinc Co., Palmerton, Pa.; Sherwin-Williams Co., Chicago; United Color & Pigment Co., Newark, N. J.

<sup>a</sup> In short tons, domestic & imported barytes; <sup>b</sup> Location of plants; <sup>c</sup> Including only those using barytes.

## Appendix XXXII

## U. S. PRODUCTION OF DENATURED ALCOHOL \*

Year (fiscal)	Total Alcohol Produced <i>proof</i> gallons	Denatur- ing Plants <i>number</i>	Alcohol Withdrawn <i>proof</i> gallons	Completely Denatured Alcohol <i>wine</i> gallons	Specially Denatured Alcohol <i>wine</i> gallons	Total Denatured Alcohol <i>wine</i> gallons
1923..	122,402,849.81	76	105,819,404.9	27,128,229.54	30,436,913.14	57,565,142.68
1924..	135,897,725.83	83	121,576,196.1	34,602,003.72	33,085,292.04	67,687,295.76
1925..	166,165,517.81	91	148,970,220.9	46,983,969.88	34,824,303.28	81,808,273.16
1926..	202,271,670.32	97	191,670,107.2	65,881,442.43	39,494,443.80	105,375,886.23
1927..	184,323,016.97	94	170,633,436.7	56,093,748.16	39,354,928.48	95,448,676.64
1928..	169,149,904.83	82	159,689,378.2	46,966,601.28	45,451,424.28	92,448,676.64
1929..	200,833,051.08	77	182,778,966.1	52,405,451.92	54,555,006.15	106,960,458.07

\* From Bur. Ind. Alcohol, *Statistics Concerning Intoxicating Liquors*, Dec. 1933.

## Appendix XXXIII

## WOOD CHEMICALS PRODUCED IN U. S.

(From *Census of Mfrs.*)

	1923	1925	1927	1929
<i>Acetate of Lime</i>				
No. firms .....	72	63	53	49
Total production, tons ...	80,788	81,723	78,140	—
Made & consumed .....	8,494	9,071	9,124	—
Sales .....	72,294	72,652	65,016	58,163
Value .....	\$4,763,403	\$3,437,384	\$4,021,292	\$4,695,449
<i>Methanol</i>				
No. firms .....	77	67	57	53
Crude, No. firms .....	74	62	55	51
Total production, gal...	9,128,852	8,643,848	8,008,838	8,355,189
Made & consumed...	2,091,419	2,795,203	2,276,139	3,254,112
Sales .....	7,037,433	5,848,645	5,732,699	5,101,077
Value .....	\$4,108,512	\$2,025,680	\$2,072,101	\$1,794,392
Refined, No. firms .....	11	13	9	11
Gallons .....	5,037,245	5,870,658	5,001,832	6,676,321
Value .....	\$4,818,695	\$3,390,223	\$2,951,793	\$3,907,111
Methyl Acetone, No. firms.	5	6	6	7
Pounds .....	6,367,386	3,644,272	2,603,520	4,675,140
Value .....	\$878,779	\$457,589	\$352,947	\$574,736
<i>Miscellaneous: Acetic Acid,</i>				
<i>Acetic Anhydride, Ethyl</i>				
<i>Acetate, etc.,* Value ..</i>				
	\$1,221,196	\$1,355,155	\$1,432,112	\$3,840,575

\* Primarily products of chemical industry.

## Appendix XXXIV

U. S. PRODUCTION OF COAL-TAR AND OTHER SYNTHETIC ORGANIC COMPOUNDS,  
1923-29, WITH LIST OF IMPORTANT EXAMPLES <sup>a</sup>(From Tariff Comm., *Census of Dyes.*)

<i>Dyes</i>				
Year	Production	Sales	Value of Sales	No. Firms
1923.....	93,667,524 lb.	86,567,446 lb.	\$47,223,161	88
1924.....	68,679,000	64,961,433	35,012,400	78
1925.....	86,345,438	79,303,451	37,468,332	75
1926.....	87,978,624	86,255,836	36,312,648	61
1927.....	95,167,905	98,339,204	38,532,795	55
1928.....	96,625,451	93,302,708	39,792,039	53
1929.....	111,421,505	106,070,887	45,842,130	54
<i>Flavors</i>				
1923.....	1,458,024 lb.	1,442,387 lb.	\$1,780,313	16
1924.....	1,750,555	1,691,863	1,471,089	16
1925.....	2,207,102	2,148,904	1,409,311	15
1926.....	2,857,913	2,629,126	1,482,697	15
1927.....	2,205,472	2,235,791	1,435,445	16
1928.....	1,746,350	1,966,467	1,296,034	14
1929.....	2,292,450	2,253,414	3,517,182	10
<i>Intermediates</i>				
1923.....	231,393,871 lb.	83,582,808 lb.	\$18,916,058	103
1924.....	186,596,562	76,897,521	18,164,334	94
1925.....	210,699,779	86,066,651	19,756,200	92
1926.....	229,653,802	86,916,836	18,990,042	78
1927.....	240,073,184	92,917,439	20,127,459	72
1928.....	279,274,807	115,837,340	24,126,473	77
1929.....	354,487,718	148,711,591	28,871,572	77
<i>Lakes</i>				
1923.....	13,079,115 lb.	12,627,359 lb.	\$5,124,732	43
1924.....	9,343,147	9,281,673	4,045,799	46
1925.....	11,414,753	11,308,444	5,544,371	44
1926.....	11,796,203	11,425,139	6,023,011	43
1927.....	11,601,507	11,629,740	6,446,508	40
1928.....	12,127,242	12,045,435	6,589,166	38
1929.....	13,244,676	12,907,914	7,262,543	37

<sup>a</sup> Total sales value of dyes & other finished coal-tar products: 1923—\$65,898,177, 1924—\$55,932,580, 1925—\$60,811,400, 1926—\$59,533,445, 1927—\$61,272,645, 1928—\$65,762,945, 1929—\$77,247,361; <sup>b</sup> Including tanning materials; <sup>c</sup> Included in "Synthetic tanning materials" prior to 1927; <sup>d</sup> After 1926, resins stated separately; <sup>e</sup> Including photographic chemicals; <sup>f</sup> Total production for other yrs. undisclosed usually because too few mfrs.; <sup>g</sup> Including salt; <sup>h</sup> Production of Commercial Solvents Corp., *Wall St. J.*, Apr. 8, 1929, June 13, 1930; <sup>i</sup> Including technical; <sup>j</sup> Sales.

*Medicinals*

Year	Production	Sales	Value of Sales	No. Firms
1923.....	3,273,085 lb.	2,995,448 lb.	\$4,720,253	32
1924.....	2,967,944	2,688,329	5,178,099	29
1925.....	3,237,796	3,294,827	6,331,918	30
1926.....	3,696,196	3,593,226	6,742,128	26
1927.....	3,598,839	3,548,556	6,819,487	24
1928.....	4,088,393	4,004,557	8,650,838	23
1929.....	5,000,205	4,745,054	8,358,526	24

*Perfumes*

1923.....	1,365,449 lb.	1,275,432 lb.	\$ 789,431	20
1924.....	1,895,267	1,945,488	945,773	19
1925.....	2,335,024	2,370,728	883,617	19
1926.....	1,922,666	1,731,887	820,264	17
1927.....	1,998,987	2,025,614	991,922	18
1928.....	1,577,718	1,619,476	1,000,001	18
1929.....	1,599,430	1,480,368	1,082,602	16

*Photographic chemicals*

1923.*.....	343,289 lb.	321,083 lb.	\$443,697	5
1924.....	316,183	321,865	461,379	5
1925.....	327,041	348,842	475,095	5
1926.....	393,426	387,698	504,941	5
1927.....	5,332,483 <sup>b</sup>	5,352,617 <sup>b</sup>	951,832 <sup>b</sup>	6 <sup>b</sup>
1928.....	478,979	493,825	696,101	5
1929.....	580,947	580,150	790,981	5

*Synthetic resins<sup>c</sup>*

1927.....	13,452,230 lb.	13,084,313 lb.	\$ 6,094,656	7
1928.....	20,411,465	20,778,856	7,211,958	9
1929.....	33,036,490	30,660,513	10,393,397	11

*Synthetic tanning materials & resins<sup>d</sup>*

1923.....	9,763,685 lb.	10,068,431 lb.	\$5,816,590	3 & 2
1924.....	12,778,115	12,745,458	8,818,041	3 & 2
1925.....	14,687,074	13,896,583	8,698,756	1 & 2
1926.....	14,106,993	14,325,724	7,647,756	2 & 2
1927.....	5,332,483 <sup>e</sup>	5,352,617 <sup>e</sup>	951,832 <sup>e</sup>	2 <sup>e</sup>
1928.....	6,587,501	6,685,490	526,808	4
1929.....	—	—	—	2

*Synthetic organic compounds (non-coal-tar)*

1923.....	90,597,712 lb.	67,727,067 lb.	\$13,875,521	—
1924.....	115,817,865	85,933,461	20,604,717	—
1925.....	156,878,013	114,626,209	23,632,779	—
1926.....	214,842,513	168,712,158	29,719,270	—
1927.....	280,992,825	201,548,089	36,600,628	—
1928.....	384,564,836	257,077,856	45,928,945	—
1929.....	633,192,215	405,185,980	65,117,651	—



<i>Acetaldehyde</i> <sup>t</sup>			1926.....	565,010 lb.	9 firms
1924.....	278,967 lb.	4 firms	1927.....	2,703,844	8
			1928.....	4,801,263	7
<i>Acetanilide, technical</i> <sup>t</sup>			<i>Amyl salicylate</i>		
1923.....	249,099 lb. <sup>1</sup>	6 firms	1923.....	9,217 lb.	8 firms
1924.....	61,820 <sup>1</sup>	5	1924.....	8,692	8
1927.....	1,990,242	6	1925.....	11,079	8
1928.....	1,539,935	4	1926.....	13,789	8
<i>Acetanilide, U.S.P.</i>			1927.....	16,959	7
1923.....	564,498 lb.	4 firms	1928.....	21,487	6
1924.....	425,950	3	1929.....	27,765	6
1925.....	158,756	3	<i>Aniline oil</i>		
1926.....	458,927	3	1923.....	26,671,961 lb.	8 firms
1927.....	366,842	4	1924.....	22,257,354	9
1928.....	480,273	3	1925.....	24,989,301	7
1929.....	355,019	3	1926.....	26,028,939	8
<i>Acetylsalicylic acid</i>			1927.....	27,084,227	7
1923.....	1,525,795 lb.	4 firms	1928.....	29,770,194	7
1924.....	1,366,530	4	1929.....	33,743,270	8
1925.....	1,499,166	4	<i>Anthraquinone vat blue GCD (C.I. 1113)</i> <sup>t</sup>		
1926.....	1,823,748	4	1927.....	1,052,967 lb.	3 firms
1927.....	1,715,686	5	1928.....	851,159	4
1928.....	1,816,015	4	1929.....	674,805	4
1929.....	2,710,374	4	<i>Auramine (C.I. 655)</i> <sup>t</sup>		
<i>Acid (agalma) black 10B (C.I. 246)</i>			1923.....	471,359 lb.	4 firms
1923.....	2,568,458 lb.	15 firms	1924.....	390,192	5
1924.....	1,271,980	13	1925.....	528,840 <sup>1</sup>	4
1925.....	1,191,137	14	1928.....	920,821	3
1926.....	1,234,258	14	1929.....	1,224,158	4
1927.....	1,496,258	11	<i>Benzidine, base</i>		
1928.....	1,917,132	12	1923.....	768,880 lb.	6 firms
1929.....	1,433,596	10	1924.....	1,351,814 <sup>u</sup>	10
<i>1-Amino-2-naphthol-4-sulfonic acid</i>			1925.....	1,182,338 <sup>u</sup>	9
1923.....	792,639 lb.	10 firms	1926.....	1,516,301 <sup>u</sup>	7
1924.....	505,741	11	1927.....	1,306,369 <sup>u</sup>	4
1925.....	531,928	7	1928.....	739,802	5
1926.....	638,772	8	1929.....	1,303,728	4
1927.....	684,134	5	<i>Benzyl acetate</i> <sup>t</sup>		
1928.....	966,689	6	1923.....	21,937 lb.	7 firms
1929.....	1,013,523	8	1924.....	28,390	8
<i>Amyl acetate, n- &amp; sec.</i>			1925.....	27,661	9
1923.....	3,207,022 lb.	12 firms	1926.....	39,473	8
1924.....	1,514,123	13	1927.....	60,442	7
1925.....	1,338,456	12	1928.....	95,394	7
1926.....	2,702,015	14	<i>Benzyl alcohol</i> <sup>t</sup>		
1927.....	2,421,301	16	1923.....	12,080 lb.	5 firms
1928.....	4,290,117	14	1924.....	14,773	7
1929.....	5,832,145	13	1925.....	10,753	8
<i>Amyl alcohol, n- &amp; sec.</i> <sup>t</sup>			1926.....	35,441	7
1924.....	149,654 lb.	6 firms	1927.....	48,902	6
1925.....	154,990	7	1928.....	32,702	6

*Benzyl benzoate*<sup>t</sup>

1923.....	29,185 lb.	7 firms
1924.....	25,318 <sup>1</sup>	7
1925.....	13,483	7
1926.....	28,009	7
1927.....	33,094	5
1928.....	26,282	5

1925.....	851,540 lb.	11 firms
1926.....	896,271	9
1927.....	1,134,397	10
1928.....	1,275,149	9
1929.....	1,387,168	9

*Butyl acetate, n- & sec.*

1923.....	1,816,086 lb.	10 firms
1924.....	7,095,662	13
1925.....	16,472,914	10
1926.....	27,240,117	9
1927.....	26,304,243	11
1928.....	30,029,505	9
1929.....	38,780,656	9

*Cinchophen*

1923.....	32,710 lb.	3 firms
1924.....	56,003	5
1925.....	60,722	6
1926.....	79,632	6
1927.....	84,212	6
1928.....	94,330	5
1929.....	99,538	7

*Cinnamaldehyde*<sup>t</sup>

1923.....	1,422 lb.	5 firms
1924.....	9,284	4

*Butyl alcohol*<sup>t, h</sup>

1923.....	4,613,396 lb.	3 firms
1924.....	14,250,062	2
1926.....	41,517,961	2
1927.....	48,922,561	2
1928.....	49,860,798	2
1929.....	67,500,000	2

*Coumarin, synthetic*

1923.....	114,682 lb.	6 firms
1924.....	129,111	5
1925.....	104,363	6
1926.....	146,640	6
1927.....	112,571	5
1928.....	121,344	6
1929.....	108,326	5

*Butyl propionate*<sup>t</sup>

1927.....	1,731,895 lb.	5 firms
1928.....	3,039,899	3

*Dibutyl phthalate*<sup>t</sup>

1928.....	3,130,380 lb.	4 firms
1929.....	4,749,776	4

*Carbon tetrachloride*

1923.....	13,513,644 lb.	4 firms
1924.....	14,275,057	3
1925.....	16,163,104	5
1926.....	18,998,848	6
1927.....	16,550,026	6
1928.....	19,764,908	4
1929.....	34,719,934	4

*p-Dichlorobenzene*

1923.....	1,419,879 lb.	5 firms
1924.....	1,038,812	7
1925.....	1,968,733	7
1926.....	2,474,044	6
1927.....	2,770,699	4
1928.....	4,010,122	5
1929.....	5,616,475	4

*Chlorobenzene, mono*

1923.....	7,024,604 lb.	4 firms
1924.....	8,288,459	3
1925.....	8,687,989	4
1926.....	10,400,260	4
1927.....	13,962,263	4
1928.....	17,835,614	4
1929.....	5,257,306 <sup>1</sup>	5

*Diethyl phthalate*<sup>t</sup>

1923.....	1,250,280 lb.	10 firms
1924.....	1,676,911	15
1925.....	2,099,181	13
1926.....	1,044,218	10
1927.....	983,894	8
1928.....	1,152,662	6

*Chloroform*<sup>t</sup>

1923.....	1,585,250 lb.	4 firms
1924.....	1,301,492	4
1925.....	1,305,868	4
1926.....	1,909,660	3
1929.....	2,767,301	3

*Dimethylaniline*

1923.....	2,681,751 lb.	6 firms
1924.....	2,830,798	6
1925.....	2,417,625	5
1926.....	2,831,911	5
1927.....	3,003,869	3
1928.....	3,694,549	4
1929.....	3,831,006	4

*Chrome blue (salicine) black U*

1923.....	1,242,283 lb.	14 firms
1924.....	765,708	13

*Dinitrobenzene*

1923.....	2,064,150 lb.	4 firms
1924.....	1,465,566	4
1925.....	1,606,518	3
1926.....	1,340,392	3
1927.....	1,587,411	3
1928.....	1,721,981	4
1929.....	1,831,167	3

*Dinitrochlorobenzene*

1923.....	7,445,467 lb.	5 firms
1924.....	6,024,092	5
1925.....	7,145,798	5
1926.....	6,498,194	4
1927.....	8,039,445	3
1928.....	6,191,832	3
1929.....	7,317,164	3

*Dinitrotoluene<sup>c</sup>*

1923.....	4,304,198 lb.	6 firms
1924.....	2,461,565	6
1926.....	6,176,322	9
1927.....	4,682,738	7
1928.....	5,020,846	6

*Diphenylguanidine*

1923.....	867,019 lb.	6 firms
1924.....	1,034,099	4
1925.....	1,204,780	5
1926.....	1,530,863	7
1927.....	1,552,216	7
1928.....	1,871,424	6
1929.....	2,444,226	5

*Diphenyloxide<sup>c</sup>*

1924.....	95,080 lb.	4 firms
1926.....	58,042	4

*Direct black EW (C.I. 581)*

1923.....	6,957,581 lb.	10 firms
1924.....	5,466,392	9
1925.....	5,142,147	9
1926.....	6,191,917	7
1927.....	5,916,562	8
1928.....	7,252,626	8
1929.....	6,964,124	7

*Direct (benzo) blue 2B (C.I. 406)*

1923.....	1,065,539 lb.	13 firms
1924.....	701,715	12
1925.....	787,074	12
1926.....	1,074,619	9
1927.....	811,803	11
1928.....	1,268,150	12
1929.....	1,352,732	13

*Di-o-tolylguanidine<sup>c</sup>*

1927.....	1,597,655 lb.	3 firms
1928.....	1,346,297	3

*Ethyl acetate, 85%*

1923.....	25,887,720 lb.	11 firms
1924.....	27,222,761	12
1925.....	26,678,737	12
1926.....	43,661,465	13
1927.....	49,203,156	14
1928.....	58,578,026	13
1929.....	73,895,640	11

*Ethyl bromide<sup>c</sup>*

1923.....	124,842 lb.	5 firms
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*Ethyl chloride<sup>c</sup>*

1923.....	270,180 lb.	9 firms
1924.....	851,303	9

*Ethyl ether, U.S.P.*

1923 <sup>h</sup> .....	5,104,157 lb.	6 firms
1924 <sup>h</sup> .....	5,314,928	8
1925.....	5,355,050	3
1926.....	5,896,016	4
1927.....	5,855,462	4
1928.....	5,933,297	4
1929.....	6,147,393	4

*Formaldehyde, 40%*

1923.....	24,081,188 lb.	6 firms
1924.....	26,155,175	5
1925.....	31,455,716	5
1926.....	31,953,204	4
1927.....	29,920,072	4
1928.....	38,717,732	4
1929.....	51,786,422	4

*Gallic acid*

1923.....	469,941 lb.	3 firms
1924.....	550,378	3
1925.....	550,604	3
1926.....	573,842	3
1927.....	515,876	3
1928.....	432,571	3
1929.....	458,389	3

*H acid*

1923.....	3,462,664 lb.	6 firms
1924.....	2,219,858	4
1925.....	2,273,439	4
1926.....	2,270,696	4
1927.....	2,404,168	5
1928.....	3,221,941	5
1929.....	2,965,637	5

*Hexamethylenetetramine*

1923.....	1,381,073 lb.	4 firms
1924.....	1,288,034	3
1925.....	1,657,993	4
1926.....	1,495,220	3

1927.....	1,315,213 lb.	3 firms	1927.....	1,007,708 lb.	6 firms
1928.....	1,661,645	3	1928.....	1,286,754	6
1929.....	2,368,020	3	1929.....	1,205,283	6
<i>Hydroquinone<sup>t</sup></i>			<i>β-Naphthol, technical<sup>t</sup></i>		
1923.....	230,079 lb.	3 firms	1923.....	5,741,355 lb.	6 firms
1924.....	203,464	3	1924.....	3,745,690	5
1925.....	208,857	3	1925.....	5,141,903	4
1926.....	257,038	3	1927.....	6,143,613	4
<i>Indigo, 20% synthetic</i>			<i>α-Naphthylamine<sup>t</sup></i>		
1923.....	28,347,259 lb.	3 firms	1923.....	862,518 lb. <sup>1</sup>	3 firms
1924.....	19,996,703	3	1928.....	2,697,340	3
1925.....	29,121,817	3	1929.....	3,801,144	3
1926.....	25,701,530	3	<i>Neoarsphenamine</i>		
1927.....	28,438,166	3	1923.....	3,365 lb.	6 firms
1928.....	25,861,680	3	1924.....	3,220	6
1929.....	29,320,270	3	1925.....	3,289	6
<i>Koch's acid<sup>t</sup></i>			1926.....	4,113	6
1923.....	3,524,246 lb.	3 firms	1927.....	3,889	6
1924.....	2,840,135	4	1928.....	4,814	6
1925.....	2,746,183	4	1929.....	5,525	6
1927.....	2,806,239	4	<i>Nigrosine (C.I. 865)</i>		
1928.....	3,627,786	4	1923.....	1,389,106 lb.	6 firms
<i>Methyl salicylate</i>			1924.....	1,241,330	6
1923.....	967,505 lb.	8 firms	1925.....	1,089,298	4
1924.....	1,282,505	8	1926.....	1,176,851	4
1925.....	1,819,822	6	1927.....	1,219,797	4
1926.....	2,456,684	7	1928.....	1,625,173	4
1927.....	1,836,397	6	1929.....	1,517,171	4
1928.....	1,338,851	5	<i>p-Nitroaniline<sup>t</sup></i>		
1929.....	1,572,187	5	1923.....	2,008,003 lb.	5 firms
<i>Methyl violet (C.I. 680)</i>			1924.....	964,344	5
1923.....	578,183 lb.	8 firms	1925.....	1,565,917	4
1924.....	543,031	8	1926.....	633,048	4
1925.....	649,900	8	1927.....	747,764	3
1926.....	753,231	6	<i>Nitrobenzene (oil of mirbane)</i>		
1927.....	673,832	6	1923.....	45,068,881 lb.	6 firms
1928.....	672,878	6	1924.....	40,012,976	6
1929.....	788,136	6	1925.....	31,264,543	5
<i>Naphthalene, refined flake</i>			1926.....	42,934,570	6
1923.....	28,183,784 lb.	10 firms	1927.....	41,774,036	5
1924.....	15,323,577	7	1928.....	43,120,288	5
1925.....	17,580,683	4	1929.....	47,931,925	7
1926.....	18,071,619	6	<i>Nitrotoluene</i>		
1927.....	21,233,131	5	1923.....	7,005,352 lb.	6 firms
1928.....	24,992,092	5	1924.....	5,151,589	6
1929.....	31,143,716	5	1925.....	5,574,193	6
<i>Naphthionic acid</i>			1926.....	7,009,377	7
1923.....	1,491,963 lb.	9 firms	1927.....	5,731,718	5
1924.....	1,311,795	9	1928.....	8,363,045	5
1925.....	1,180,218	7	1929.....	8,036,397	6
1926.....	1,313,931	6			

*o*-Nitrotoluene

1923.....	3,764,647 lb.	6 firms
1924.....	2,056,361	5
1925.....	3,336,648	6
1926.....	3,828,677	6
1927.....	3,402,714	3
1928.....	3,888,799	3
1929.....	3,648,335	3

*p*-Nitrotoluene

1923.....	2,285,120 lb.	6 firms
1924.....	1,351,631	5
1925.....	1,748,991	6
1926.....	2,046,810	6
1927.....	1,808,028	3
1928.....	2,038,863	3
1929.....	1,888,720	3

## Orange II (C.I. 151)

1923.....	1,617,668 lb.	12 firms
1924.....	1,163,021	8
1925.....	1,359,304	8
1926.....	1,194,535	7
1927.....	1,423,969	5
1928.....	1,419,416	5
1929.....	1,615,441	5

*Para red lakes*

1923.....	3,379,767 lb.	29 firms
1924.....	2,619,770	30
1925.....	2,328,113	31
1926.....	3,005,179	30
1927.....	2,103,795	28
1928.....	2,251,393	28
1929.....	2,063,201	24

*Paraformaldehyde*<sup>t</sup>

1923.....	112,846 lb.	3 firms
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*Phenol*

1923.....	3,310,911 lb.	8 firms
1924.....	10,521,944	7
1925.....	14,734,065	7
1926.....	8,691,181	6
1927.....	8,041,082	4
1928.....	10,227,489	6
1929.....	24,177,618	5

*Phenolphthalein*<sup>t</sup>

1928.....	372,785 lb.	3 firms
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*Phenolsulfonates*<sup>t</sup>

1923.....	208,902 lb.	4 firms
1924.....	197,644	4
1925.....	163,723	4

*Phenylglycine & sodium salt*<sup>t</sup>

1923.....	11,166,650 lb.	3 firms
1926.....	8,756,452	3
1927.....	9,738,449	3

*Phthalic acid & anhydride*

1923.....	2,343,802 lb.	4 firms
1924.....	2,787,308	4
1925.....	3,900,332	4
1926.....	4,379,108	4
1927.....	4,549,820	4
1928.....	6,030,854	4
1929.....	9,168,946	4

*Procaine*<sup>t</sup>

1924.....	3,790 lb.	3 firms
1926.....	6,702	3
1928.....	7,952	3

*Pyrogallol*

1923.....	235,389 lb.	3 firms
1924.....	238,587	3
1925.....	174,251	3
1926.....	189,847	3
1927.....	166,472 <sup>1</sup>	3
1928.....	142,335	3
1929.....	134,994	3

*Saccharin*<sup>t</sup>

1923.....	340,944 lb.	3 firms
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*Salicylic acid, technical*<sup>t</sup>

1923.....	2,857,281 lb.	6 firms
1924.....	1,757,581	3
1925.....	2,563,102	3
1926.....	4,083,341	5
1927.....	3,269,243	5
1928.....	2,977,279	3

*Salicylic acid, U.S.P.*

1923.....	1,330,048 lb.	4 firms
1924.....	2,196,292	5
1925.....	2,510,876	4
1926.....	2,966,757	4
1927.....	2,618,829	3
1928.....	2,518,591	3
1929.....	4,219,186	3

*Salol*<sup>t</sup>

1923.....	98,597 lb.	3 firms
1925.....	118,869	3
1926.....	84,182	3
1927.....	51,504	3

*Sodium benzoate*

1923.....	749,885 lb.	4 firms
1924.....	860,810	7

1925.....	800,841 lb.	7 firms
1926.....	897,848	7
1927.....	1,025,835	6
1928.....	1,027,370	6
1929.....	1,121,569	6

*Sodium salicylate*

1923.....	416,382 lb.	5 firms
1924.....	412,707	5
1925.....	415,465	4
1926.....	469,345	4
1927.....	492,558	4
1928.....	456,195	4
1929.....	455,462	4

*Sulfanilic acid*

1923.....	1,861,884 lb.	12 firms
1924.....	1,385,441	10
1925.....	1,407,470	9
1926.....	1,546,120	9
1927.....	1,328,475	8
1928.....	1,633,123	7
1929.....	1,677,077	6

*Sulfur black*

1923.....	16,276,409 lb.	7 firms
1924.....	11,728,790	5
1925.....	16,587,828	5
1926.....	16,704,636	5
1927.....	19,001,783	5
1928.....	14,354,755	4
1929.....	18,121,621	4

*Sulfur brown*

1923.....	2,203,893 lb.	16 firms
1924.....	1,401,334	14
1925.....	1,832,364	16
1926.....	1,389,423	13
1927.....	1,703,172	12
1928.....	1,729,647	12
1929.....	1,655,316	12

*Terpineol<sup>t</sup>*

1923.....	322,337 lb.	4 firms
1924.....	295,532	4
1925.....	157,626 <sup>1</sup>	4
1926.....	235,331	4

*Thiocarbanilide*

1923.....	3,309,414 lb.	6 firms
1924.....	3,397,397	7
1925.....	2,352,006	5
1926.....	1,493,396	5
1927.....	930,808	5
1928.....	893,366	4
1929.....	923,091	4

*o-Toluidine*

1923.....	1,440,884 lb.	7 firms
1924.....	1,184,550	5
1925.....	2,031,899	7
1926.....	2,430,166	7
1927.....	2,289,728	4
1928.....	2,573,611	4
1929.....	2,339,436	4

*p-Toluidine*

1923.....	1,060,848 lb.	8 firms
1924.....	566,528	5
1925.....	941,927	6
1926.....	505,362	6
1927.....	839,373	4
1928.....	906,033	3
1929.....	1,151,483	3

*m-Tolylenediamine*

1923.....	1,179,457 lb.	13 firms
1924.....	870,794	13
1925.....	770,265	10
1926.....	688,303	9
1927.....	804,890	8
1928.....	898,435	7
1929.....	911,351	7

*Vanillin*

1923.....	269,941 lb.	6 firms
1924.....	320,242	6
1925.....	315,344	5
1926.....	357,300	6
1927.....	301,251	6
1928.....	281,694	8
1929.....	337,083	7

*Xanthates<sup>t</sup>*

1927.....	4,700,610 lb.	4 firms
1928.....	5,458,306	4

## Appendix XXXV

## U. S. PRODUCTION OF COAL-TAR CRUDES

(From Tariff Comm., *Census of Dyes.*)

Year	<i>Benzene</i>		Total Production <sup>a</sup>	
	Coke-Oven Sales			
	<i>gallons</i>	<i>gallons</i>	<i>value</i>	
1923.....	16,724,182	17,154,088	\$3,968,742	
1924.....	17,740,608	18,417,542	3,901,629	
1925.....	21,816,386	22,607,962	5,070,245	
1926.....	21,987,790	22,374,838	5,175,206	
1927.....	21,193,807	21,579,589	4,474,972	
1928.....	21,452,973	21,942,430	4,330,557	
1929.....	24,558,745	25,119,013	5,310,107	
	<i>Naphthalene<sup>b</sup></i>			
	<i>pounds</i>	<i>pounds</i>	<i>value</i>	
1923.....	11,245,633	53,814,195	\$934,104	
1924.....	8,219,073	44,102,878	602,541	
1925.....	9,900,517	45,301,726	652,017	
1926.....	7,723,223	53,059,189	594,296	
1927.....	7,848,224	53,176,660	557,884	
1928.....	10,937,429	46,157,425	531,752	
1929.....	19,659,367	39,201,046	687,763	
	<i>Toluene</i>			
	<i>gallons</i>	<i>gallons</i>	<i>value</i>	
1923.....	2,634,783	( <sup>c</sup> )	( <sup>c</sup> )	
1924.....	3,231,502	( <sup>c</sup> )	( <sup>c</sup> )	
1925.....	5,038,147	( <sup>c</sup> )	( <sup>c</sup> )	
1926.....	8,650,605	( <sup>c</sup> )	( <sup>c</sup> )	
1927.....	11,784,984	( <sup>c</sup> )	( <sup>c</sup> )	
1928.....	16,181,650	( <sup>c</sup> )	( <sup>c</sup> )	
1929.....	17,064,206	( <sup>c</sup> )	( <sup>c</sup> )	

<sup>a</sup> Including estimates from firms not reporting; <sup>b</sup> For production of flake naphthalene, see Appendix XXXIV; <sup>c</sup> Figs. not disclosed.

## Appendix XXXVI

## NEW PROCESSES FOR PHENOL AND ANILINE

By William J. Hale\*

The hydrolysis of benzene halides has ever been an intriguing problem. But with the close of World War I, with 15,000,000 pounds of phenol in the hands of the Government, and offered at 12¢ a pound, there was little urge to proceed with these hydrolytic studies. However, Dr. Herbert H. Dow, founder of Dow Chemical, had earlier experimented with bromobenzene, a Dow Chemical product [U. S. Pat. 1,274,394 (1918)], and

\* To author, July 28, 1946.

entertained a quiet suspicion that ways and means might be found whereby bromobenzene would yield more readily than chlorobenzene to the action of certain hydrolytic agents.

Drs. Edgar C. Britton, William H. Williams, and the writer took up this work in 1922. Unfortunately we could find nothing in favor of bromobenzene hydrolysis. In general the work on chlorobenzene was fairly well known. In 1913 two German chemists, Kurt H. Meyer and Friedrich Bergius, had effected its hydrolysis with high conversion, but with unpredictable proportions of diphenyloxide always appearing. In 1917, in this country, J. W. Aylsworth also had advanced this study by employing a continuous tubular system through which chlorobenzene and a strong aqueous caustic solution were pumped. Though complete hydrolysis in one hour was here attained at temperatures from 340 to 390° C., the accumulation of tarry residues surpassed all else.

It was not long before we recognized that at these higher temperatures a strong caustic soda solution attacked the metal casing, developing hydrogen and thus contributing to a higher percentage of tarry material, whereas under these same conditions a dilute caustic solution was not particularly corrosive yet led to formation of a greater percentage of diphenyloxide. Our choice lay within a 6 to 12% range of caustic in aqueous solution. With this reactant and 2¼ molar proportions of chlorobenzene, at 370° to 380° C., we readily secured a complete conversion in one hour in rotating iron bombs, in which 1/9 was diphenyloxide and 8/9ths phenol.

Earlier experimenters reported that copper played the role of a good catalyst in these hydrolyses. Our work confirmed such reports, especially at lower temperatures. However, after a search of catalysts of all types, we soon elected to introduce diphenyloxide itself into the reaction mixture, hoping that it, like so many other ethers and esters that aid in splitting off halogen from organic compounds, might display some catalytic action within the liquid mass.

Much to our surprise the additional quantity of diphenyloxide, 2 to 3%, did not show up in the diphenyloxide collected at the end of the reaction! In brief, we had been operating in a range of equilibrium between phenol itself and diphenyloxide plus water. The problem was at once solved when we elected to add to the reaction mixture of chlorobenzene and caustic soda the exact proportion of diphenyloxide (about 12% of the weight of chlorobenzene) which generally accompanied the hydrolysis. In short, we simply supplied one component of the final reaction mass by introducing it at the initial stage, so that in the equilibrium ensuing within 30 minutes at about 370° C. to 380° C. at 5,000 pounds per-square-inch pressure, no further diphenyloxide was formed. This discovery was made the subject of U. S. Pat. 1,607,618 of Nov. 23, 1926 [reissue 18,129 (1931)] and issued to Dr. Britton and the writer. Other U. S. Patents on the same subject from Dow laboratories are: 1,602,766 (1926); 1,737,841-2 (1929); 1,744,961, 1,756,110 (1930); 1,789,071, 1,806,798, 1,821,800, 1,833,485 (1931); 1,868,140, 1,882,824-6 (1932); 1,907,246, 1,921,373, 1,922,695, 1,925,321 (1933); and 2,137,587 (1938).

When we overstepped this proper proportion of diphenyloxide added to the reaction mixture, we were certain to end up with higher than 100% yield of phenol, as based on the chlorobenzene input. Later we discovered that the more closely the reaction was held at the critical temperature of water (374° C.) the more nearly were optimum results obtained; furthermore, a drop in diphenyloxide introduced could be made to serve as a means of producing this same diphenyloxide commercially.

In the semiplant research we encountered much difficulty through lack of turbulent flow in the small, ¼-inch-diameter tubes. But in plant operation, with low-carbon steel tubes approaching an inch in diameter, this defect was remedied. When the plant operation got well under way late in 1923, we further observed formation of 4 or 5% tarry material, due primarily to chlorobenzene condensation with a tautomerized phenol and consisting mainly of *o*- and *p*-xenol, both of which have met with urgent demands in industry.

The commercial success of the Hale-Britton process rests not alone upon the use of a caustic concentration that will not attack the iron tubular system, but also upon the ingenious engineering device of Dr. Mark E. Putnam: U. S. Pat. 1,921,373 (1933). This is



an exothermal procedure, which provides for enclosing the tubular system within a larger tubular system and the initial passage of the incoming feed through the outer enclosure so as to take up the heat of reaction evolved from the inner tube. Thus the heat of reaction is transferred to the incoming liquor evenly and in sufficient amount to raise the temperature of said liquor itself to the point of reaction, there being additionally required merely a small flame to keep the process moving. And under such conditions the employment of a higher concentration of caustic is most appropriate, particularly from the standpoint of economy.

At the same time that hydrolytic studies on benzene halides were being conducted, ammonolytic studies were under way in the organic laboratories at Dow Chemical. J. Walter Britton was the chief associate. After full consideration of all that had gone before, we soon recognized that success lay in the maintenance of cuprous oxide catalyst in super-reduced form. Experimental work fully confirmed our deductions and U. S. Pat. 1,607,824 (1926) [reissue 17,280 (1929)] was issued to Dr. Britton and the writer.

William H. Williams contributed the idea and developed the process of returning the residual cuprous sludge left upon ammonolysis of chlorobenzene, to the next batch of chlorobenzene and excess ammonia liquor, whereby the catalyst was maintained in highest state of reduction and thus in increased activity: U. S. Pats. 1,726,170-3 (1929). In the same vein Williams reduced somewhat the formation of by-product diphenylamine by likewise returning some of this material from one operation to the following batch of chlorobenzene and ammonia liquor: U. S. Pat. 1,775,360 (1930).

The favorable temperature for ammonolysis of chlorobenzene is in the neighborhood of 240° C. Other Dow patents on these ammonolytic studies are: U. S. Pats. 1,764,869 (1930); 1,804,466 (1931); 1,840,760 (1932); 1,932,518 (1933); 2,028,065 (1936). In due order this ammonolytic batch process gave way to improvements under the direction of William H. Williams, and today the entire aniline process has virtually become a continuous system.

## Appendix XXXVII

### NEW PRODUCERS OF COAL-TAR AND OTHER SYNTHETIC ORGANIC COMPOUNDS, 1923-29 \*

(From Tariff Comm., *Census of Dyes*.)

Acids Mfg. Corp., N.Y.C. (Packer, Conn.), 1923-26; Algon Color & Chemical Corp., N.Y.C. (Elizabeth, N. J.), 1924-29; Allied Tar & Chemical Corp., N.Y.C. (Bayway, Elizabeth, N. J.), 1928-29; Alyco Mfg. Co., Bloomfield, N. J., 1923-29; American Catalin Corp., N.Y.C. (College Pt., N. Y.), 1929; American Solvents & Chemical Corp., N.Y.C. (Albany, N. Y.), 1926-29; Amido Products Co., N.Y.C. (Newark, N. J.), 1923-26; Ansbacher-Siegle Corp., Staten Is., N. Y., 1929; Apex Chemical Co., N.Y.C. (Elizabethport, N. J.), 1926, 1928-29; Atlantic Creosoting Co., Norfolk, Va., 1928-29; Atom Chemical Corp., N.Y.C., 1925-26; Auramine Corp. of America, L. I. City, N. Y., 1924.

Bakelite Corp., N.Y.C. (Bloomfield, Perth Amboy, N. J.; Chicago; Painesville, O.), 1924; Bates Chemical Co., Lansdowne, Pa., 1929; Belle Alkali Co., Belle, W. Va., 1924; Belle Chemical Products Co., Belle, W. Va., 1925; Benzol Products Co., Newark, N. J. (Piscataway, N. J.), 1924-29; E. Berghausen Chemical Co., Cincinnati, 1923-29; Brown Co., Portland, Me. (Berlin, N. H.), 1923-29; Burton T. Bush, Inc., N.Y.C. (Delawanna, N. J.), 1924-26.

Cable Chemical Works, Chicago (Cable, Wis.), 1923-25, 1928-29; California Chemical

\* Exclusive of names in Vol. III, Appendix XLVIII, which see for comment. Total no. producers: 1923-208; 1924-196; 1925-185; 1926-171; 1927-166; 1928-163; 1929-161. Location of plants in parentheses.

Corp., San Francisco (Newark, San Mateo, Chula Vista, Calif.), 1929; Celaron Co., Bridgeport, Pa., 1928; Celluloid Co., N.Y.C. (Newark, N. J.), 1923-26; Celluloid Corp., N.Y.C. (Newark, N. J.), 1927-29; Chemical & Dye Corp., Springfield, N. J. (Springfield, N. J.; Ashland, Mass.), 1928-29; Childs Pulp Colors, Inc., Bklyn., N. Y., 1925-29; Coal Tar Dyes, Inc., N.Y.C. (Newark, N. J.), 1924; Colasta Co., Hoosicks Falls, N. Y., 1927-28; Continental-Diamond Fibre Co., Newark, Del., 1929; Crown Chemical Corp., N.Y.C., 1928-29; Crown Tar Works, Denver, 1923-29; Crystal Color & Chemical Works, Saugus, Mass., 1924-29.

Albert David Chemical Co., N.Y.C. (Chicago Heights, Ill.), 1923-27; Diamond State Fibre Co. (Celaron Co.), Bridgeport, Pa., 1927; Dovan Chemical Corp., N.Y.C. (Newark, N. J.), 1923-28; Du Pont Ammonia Corp., Wilmington, Del. (Belle, W. Va.), 1929; Dyes & Chemicals, Inc., St. Louis, 1925-27; Dyes & Chemicals of N. J., Inc., Bklyn., N. Y., 1923-27.

Eastern Color Co., N.Y.C., 1924; Elko Chemical Co., Nitro, W. Va., 1927; Empire Biochemical Co., N.Y.C., 1926-28.

Federal Color Labs., Inc., Norwood, O., 1923-29; Federal Phosphorus Co., Birmingham, Ala. (Anniston, Ala.), 1929; Felton Chemical Co., Bklyn., N. Y., 1925, 1927-29; L. S. Finch Chemical Co., Los Angeles (Vernon, Calif.), 1923; Fletcher Chemical Co., S. River, N. J., 1923; Ford Motor Co., Iron Mt., Mich., 1924-29.

General Aniline Works, N.Y.C. (Grasselli, N. J.; Rensselaer, N. Y.), 1928-29; General Electric Co., Schenectady, N. Y., 1927-29; General Plastics, Inc., N. Tonawanda, N. Y., 1927-29; General Synthesis Co., Providence, R. I., 1923; Givaudan-Delawanna, Inc., Delawanna, N. J., 1927-29; Glyco Products Co., Bklyn., N. Y., 1929.

C. P. Hall Co., Akron, 1929; Hampden Paint & Chemical Co., Springfield, Mass., 1925, 1927-29; Harmon Color Works, Bklyn., N. Y., 1923-29; Henke Chemical Co., Bloomington, Ind., 1924.

Inland Tar Co., Chicago (E. Chicago, Ind.), 1929.

Jennison-Wright Co., Toledo, O., 1928.

Kent Color Corp., Bklyn., N. Y., 1923-29; Kessler Chemical Corp., Orange, N. J., 1924-29; Kober Chemical Co., Nepera Pk., N. Y., 1923.

Lazote, Inc., Wilmington, Del. (Belle, W. Va.), 1927-28; Eli Lilly & Co., Indianapolis, Ind., 1924-29; Long Island Color & Chemical Corp., L. I. City, N. Y., 1925; Spencer Lucas Co., Camden, N. J., 1926-27; Lucidol Corp., Buffalo, N. Y., 1928-29.

Maple Chemical Co., Staten Is., N. Y., 1924-25; Marietta Dyestuffs Co., Marietta, O., 1929; Mason By-Products Co., San Francisco (Waldo, Calif.), 1924; Alexander Meyer, N.Y.C., 1924; Musterole Co., Cleveland, 1927.

Neville Chemical Co., Pittsburgh, 1929; Niacet Chemicals Corp., N.Y.C. (Niagara Falls), 1926-29; Novadel Process Corp., Buffalo, N. Y., 1927; Novocol Chemical Mfg. Co., Bklyn., N. Y., 1924-29.

Orange Grove Refining Co., Lawrenceburg, Ind. (Braithwaite, La.), 1927.

Peek Chemical Works, Elizabeth, N. J., 1924-25; Petroleum Chemical Corp., N.Y.C. (Tiverton, R. I.), 1926; Portland Gas & Coke Co., Portland, Ore., 1923-29; Publicker, Inc., Philadelphia, 1929.

Reynolds Chemical Corp., Utica, N. Y., 1928-29; Rubber Service Labs. Co., Akron (Nitro, W. Va.), 1924-29.

Savell, Sayre & Co., Niagara Falls, 1927-29; Sharples Solvents Corp., Phila. (Belle, W. Va.), 1927; Harold L. Simons, Inc., L. I. City, N. Y., 1926-29; Solvay Process Co., Syracuse, N. Y. (Geddes, N. Y.), 1927-29; Somerset Aniline Works, Pluckemin, N. J., 1928; Southern Aromatics Co., Brunswick, Ga., 1925; Standard Ultramarine Co., Huntington, W. Va., 1928; Wm. J. Strange Co., Chicago, 1929; Stokes & Smith Co., Philadelphia, 1928-29.

Van Ameringen-Haebler, Inc., N.Y.C. (Elizabeth, N. J.), 1929; Victor Chemical Works, Chicago (Chicago Heights, Ill.), 1923-29.

Wailes-Dove-Hermiston Corp., N.Y.C. (Garwood, Westfield, N. J.), 1928-29; Western Industries Co., San Francisco (Stege, Calif.), 1929; Witbeck Chemical Corp., Albany, N. Y., 1924; Wolff-Alport Chemical Corp., Bklyn., N. Y., 1923-29.

## Appendix XXXVIII

## DYES AT MARIETTA, OHIO

By Graham N. Gleysteen\*

In 1914 a small company in Marietta known as the Obex Labs. made finishes for straw hats. It was headed by George LaVallee, then in his early twenties, son of C. J. LaVallee, president of the Marietta Paint & Color Co. National Gum & Mica Co., through which LaVallee sold, interested him early in the war in making dyes from logwood and in 1915 a plant was started. The chemist brought in was one Irving Spencer Clope, who later disappeared from all eyes including those of the Department of Justice which was looking for him since 1917 as a suspected German agent.

The plant grew rapidly, but after the United States entered the World War the importation of logwood from Haiti became very irregular and finally stopped altogether. The company went bankrupt, causing a loss of about \$750,000 to Marietta citizens. A committee of investors with one representative from each of Marietta's four banks attempted to run the company. Development work had been done on benzaldehyde and on malachite green. G. E. Hayward, president of one of Marietta's banks and an engineer (civil), saw possibilities. With three partners he was the owner of a small oil-producing company, the Marietta Refining Co. He made an offer for the renting of the buildings and the assets of the Obex Co., and about the end of 1918 the Marietta Refining Co. took over.

Just at this time the plant of the Katzenstein family in Nyack, which had been manufacturing malachite green, burned. Hayward made a deal with them and brought their chemist, Nicholas Kalman, to Marietta. Dr. Kalman was given the management of the plant. He brought with him his assistants, Jacob Friedman and Morris Ellis.

Malachite green was soon made on a large scale. At the Chemical Show in Chicago in 1919 enormous crystal aggregates were exhibited. But in the summer of 1920 the market broke from \$3.75 per pound to \$1.05. The Marietta Refining Co. became insolvent, although it never went through a formal bankruptcy.

The company had worked out a process for auramine and to salvage what they could, the stockholders formed a new company, the Kerin Manufacturing Co., employing as manager A. J. Kerin, a Marietta business man, and as chemists, Ellis and Friedman. Dr. Kalman brought suit for breach of contract, but when the case was finally tried in Columbus in 1925, he lost.

At that time there were only two auramine makers in America and so this turned out to be a very profitable product even though yields were very low. The company also made malachite green. For these two dyes it bought dimethylaniline from Calco and became a substantial customer. In 1924 Friedman and Ellis resigned together with the sales manager, Joseph Hollywood, to form their own company, Coal Tar Dyes, Inc., which manufactured in Newark, N. J. This company discontinued in 1925.

When Messrs. Friedman and Ellis left, the Kerin Co. was in a difficult position. It employed G. N. Gleysteen as chemist and plant manager. While negotiating with him, Calco was asked to supply a chemist. This Calco was unable to do, but it did take an option on the company good for one year. The next year was extremely profitable and Calco saw fit to exercise its option.

In the meantime the dye rhodamine B had been worked out in the Kerin laboratory. When Calco bought the plant it was not interested in acquiring the rhodamine B process, being apparently desirous of taking only the dyes which used its important intermediate dimethylaniline. This seems odd since so many small companies and some larger ones had tried unsuccessfully to make this expensive dye. In fact only three companies in the United States ever successfully made rhodamine B; the two others, Newport and du Pont, by purchased processes.

\* To author, Sept. 23, 1946.

Calco moved the machinery and stocks to Bound Brook. It left all the personnel and the buildings, which were owned by the defunct Obex Co. bondholders. The Marietta Chamber of Commerce was extremely interested in retaining the business in Marietta. It backed Gleysteen in raising capital for a plant to make rhodamine B, using the personnel and buildings of the old Kerin Co. At the same time the newly organized General Dyestuff Corp. requested the new company to make auramine for it. So the Marietta Dyestuffs Co. was organized in 1926, with Charles F. Streckler, president of the Marietta Chamber of Commerce, as president, and Gleysteen as chief chemist and works manager.

The Marietta Dyestuffs Co. turned out to be a very profitable company. With Dr. Fierz-David, under whom Gleysteen studied at Zurich, as consultant, one by one it added other dyes: rhodamine 6GDN, the quinoline yellows, malachite and brilliant green, acetate rayon colors, lake colors, such as permanent orange and lake red C, and others.

## Appendix XXXIX

### WITNESSES IN U. S. *vs.* CHEMICAL FOUNDATION, 1923

[From *Ind. Eng. Chem.* 15, 977 (1923).]

For Government: Karl Holdermann, dir., Badische Anilin u. Sodafabrik; Albert M. Patterson, pres., Textile Alliance; Harry F. Danner, treas., American Dyes Inst.; Will T. Gordon, former atty., Bur. Investigation, A. P. C. office; Frank L. Polk, Undersecy. State, 1918-19; Harry S. Brown, A. P. C. office; W. H. Swenarton, former pat. atty., Nitrate Div., Army Ordnance; G. W. Storck, C.P.A., Justice Dept.; C. R. Parmele, pres., Chino-sol Co.; Mrs. Margaret R. Wilson, Fed. Trade Comm.; Harry W. Schmits, accountant, A. P. C. office; Herman A. Metz, pres., H. A. Metz & Co.; and Thos. W. Miller, A.P.C. since 3/12/21.

For Government (rebuttal): H. J. Galloway, special asst. to Atty. Gen.; Geo. W. McCoy, dir., Hygienic Lab.; Walter G. Christiansen, research chem., Harvard Medical Sch.; Louis Freedman, research chem., H. A. Metz & Co.; Wm. O. Emery, Bur. Chem.; H. D. Gibbs, Hygienic Lab., formerly with du Pont; Paul A. Blair, pat. atty., Bur. Ordnance (Navy); and Chester N. Myers, chem., H. A. Metz & Co.

For Foundation: A. Mitchell Palmer, former A. P. C.; Francis P. Garvan, pres., Chemical Foundation; Jos. H. Choate, Jr., atty.; Ernest H. Volwiler, Abbott Labs.; B. W. Dold, public accountant; Henry B. Thompson, pres., U. S. Finishing Co.; Franklin W. Hobbs, pres., Arlington Mills; Frank D. Cheney, pres., Cheney Bros.; Andrew W. Imbrie, pres., U. S. Finishing Co.; Julius Stieglitz, U. Chicago; Wm. W. Buffum, auditor, Chemical Foundation, former chief accountant, A. P. C. office; Chas. L. Parsons, consulting chem.; Alfred H. White, prof. chem. eng., U. Mich., former Lt. Col., Nitrate Div., Army Ordnance; Harry A. Curtis, dir., Nitrogen Survey, Dept. Com., and prof. chem. eng., Yale; James F. Stiles, Jr., accountant, Abbott Labs.; Elmer K. Bolton, dir., Chem. Sect., Dyestuffs Dept., du Pont; Ernest H. Klipstein, pres., E. C. Klipstein & Sons; T. W. Still, treas., E. C. Klipstein & Sons; M. L. Crossley, chief chem., Calco Chemical Co.; James B. Eliason, comptroller, du Pont; and M. R. Poucher, dir., du Pont, prior to 1913 vice-pres., Badische Co. of N. Y.

## Appendix XL

## DISCOVERY AND DEVELOPMENT OF EPHEDRINE

By Carl L. Schmidt\*

I was (temporarily) in charge of pharmacology in the Peking Union Medical College when Chen was offered and accepted an instructorship upon completion of the work for his Ph.D. at Wisconsin in June 1923. Dr. B. E. Read (now director, Division of Biological Sciences in the Henry Lester Institute for Medical Research, Shanghai), head of the department of pharmacology at Peking since its opening in 1921, was then absent on leave, but thanks to his life-long interest in Chinese drugs we had begun studies of the pharmacological actions of the most popular of these. At the time of Chen's appointment we had already carried out more or less exhaustive tests of four of these and had found nothing to justify the Chinese confidence in them. When Chen wrote me inquiring as to what sort of work he would be expected to do, I told him our unhappy experience with famous Chinese drugs to date, expressed a rather dim view of the prospects, but said I thought we should go on because negative findings with Chinese panaceas were as important as positive ones to the practitioners of Western medicine in China.

It was on this background that Chen's uncle, owner of a Chinese drugstore in Shanghai, suggested to him that he was sure that *ma huang* had real effects. Chen brought some of the material with him to Peking, and from this he prepared a decoction which we injected into the vein of a dog at the end of a practice experiment for the student course in September 1923. Instead of the fall in blood pressure seen on intravenous injection of a crude extract of every Chinese drug we had previously studied, we saw a marked rise in pressure. The effect was far too persistent to be due to accidental contamination with epinephrine. It was evident that we were dealing with something decidedly unusual and Chen immediately began a search for the active principle of *ma huang*. Within a few days he isolated an alkaloid from it and soon had enough of the material to permit us to study it, first on animals, then on man. All this was done conjointly in Peking.

In June 1924 I returned to the United States, bringing a supply of ephedrine sulfate isolated by the Division of Chemical Products at Peking College. A laboratory was set up primarily to prepare ethyl esters of chaulmoogra (for leprosy), colloidal antimony sulfide (for leishmaniasis), and similar agents recently introduced in the treatment of diseases important to physicians in China. This batch of ephedrine was turned over to Dr. T. G. Miller who, with his associates, made the first systematic clinical study of the effects of the new drug. As a result of this publication [*Am. J. Med. Sci.* 170, 157 (1925)], there was a very considerable demand for ephedrine from clinicians all over the country. This had been anticipated and arrangements had been made to have ephedrine sulfate prepared by the Peking laboratory distributed by Frank E. Morgan & Son, one of the old, conservative apothecary shops in Philadelphia. All requests for the drug were handled by the Morgan people, as were also all financial matters pertaining thereto. Until Lilly began selling its product in 1926, this was the only source of supply in the whole world.

For several years the supply of ephedrine lagged far behind the demand. One result of this was the search, by several groups, for a synthetic product capable of replacing the natural. Work along these lines, active about 1910, was resumed in 1925 and among the resulting products were benzedrine, neosynephrine, synthetic ephedrine (ephedrine, racephedrine), pervitin, and many others, which to a considerable degree have supplanted the natural alkaloid. These points are covered in our review article in *Medicine* 1, Feb. 1930.

\* To author, Oct. 31, 1946.

## Appendix XLI

### EARLY DEVELOPMENT OF AMMONIATED SUPERPHOSPHATE

By Charles H. MacDowell\*

Perhaps the most important technical development of the late twenties was the use of ammonia directly in blending fertilizers, the ammonia combining directly with the phosphoric acid in the superphosphate. This was developed in the Armour shop. The idea of using gas-house liquor was not new. Mapes had secured a patent in the late 1850's, on its use in combination with superphosphate made from bone material. I find a formula for its use in Charleston, S. C., in the 1870's, where phosphate rock was the phosphorus source. However the product was sticky and the fertilizer had to be distributed through a horn.

In 1916 I had the Armour laboratory research the subject, and again in 1922. We found that if the superphosphate was well cured, the reversion to insoluble as figured at the time was limited. We used both aqua and anhydrous ammonia. Armour was manufacturing anhydrous ammonia from aqua for its own use and for resale. I have copies of these laboratory searches in ammoniation. In 1927 synthetic anhydrous ammonia began to replace aqua, and Armour became a buyer and distributor of this anhydrous, dropping the purchase of aqua from the Chicago By-Product Coke Company. Caldwell, president of that company and a close personal friend, came to me to find out if we could not use aqua as a fertilizer material. I told him yes, at a price, remembering our research. He named a satisfactory figure, and we began to use it almost immediately.

In 1901 we had installed tight revolving mixers for fertilizer blending, and were the first to use them. They were quite suitable for using aqua. Almost immediately we made a contract with du Pont for anhydrous at a fertilizer value, as we could use anhydrous directly from the tankcar or special storage. The ammonia was introduced directly into the mixer.

A little later, desiring to have some nitrate form of nitrogen in the blend, I instructed Harry C. Moore, our chief chemist, to ascertain if ammonium nitrate would be soluble in anhydrous ammonia. He found it is and that the vapor pressure was reduced to a point where the solution could be shipped in an ordinary tankcar rather than in the specially built and expensive car used to ship anhydrous. Patents were obtained: U. S. Pat. 1,889,125, granted to me, was filed Feb. 1, 1929, and patented Nov. 29, 1932; Moore's U. S. Pat. 1,931,768, also applied for Feb. 1, 1929, was granted Oct. 24, 1933. As I recall there were other patents, but I do not have copies of them. These patents marked a revolution in fertilizer manufacturing technique. They were sold after my retirement to Allied Chemical.

The response of the trade to these developments was immediate. Although many companies were still using floor mixing and did not operate closed mixers, by 1944 something like 140,000 tons of nitrogen were used in these solution mixtures or as anhydrous.

Other companies prepared solution mixtures, du Pont having one in which synthetic urea was substituted for ammonium nitrate. The technique we developed produced dry drillable blends and improved the mechanical condition of mixed fertilizers. In preparing 45% concentrated grades we also pumped liquid phosphoric acid into the mixers with the nitrogen and potash carriers and triple superphosphate, thus doing away with complicated liquid solutions and producing in pellet form a dry drillable product.

\* To author, Feb. 10, 1946.

## Appendix XLII

## CODE OF TRADE PRACTICES FOR THE FERTILIZER INDUSTRY

(From *O.P.D. Repr.* 22, Jan. 17, 1927.)

The following code has been formulated with a view to eliminating waste and unfair trade practices which have been prevalent in the fertilizer industry and which have led to demoralization which is disastrous to the manufacturers and which in the long run cannot but also operate to the detriment of the consumers:—

1. *Sound Accounting Methods*—Manufacturers should recognize the sound principle that in manufacturing and selling their product cost should be accurately determined and carefully considered. A scientific system of cost accounting should be established and applied in order that manufacturers may know accurately the cost of their product and the relation of price thereto. In this connection the attention of manufacturers is called to a recent study entitled "Cost Accounting and Cost Estimating," prepared by the cost accounting committee of the National Fertilizer Association.

2. *Elimination of Waste*—Wasteful selling methods should be eliminated. A multiplicity of grades adds materially to the cost of mixed fertilizers and, as pointed out by the Federal Trade Commission in its investigation of the fertilizer industry, there is no economic justification therefor. A reduction of grades is therefore recommended as a measure of economy. It is further recommended that the manufacturers avoid the practice of making up fertilizer (actually of standard grades) for sale under private brands, and also the practice of compounding special formulas for individual buyers.

Since freight rates constitute a material portion of the cost of fertilizer, it is recommended that manufacturers, who are primarily wholesalers, market their product in carload lots only, so as to avoid the large differential between carload and less than carload shipments.

3. *Secret Discriminations and Rebates*—Manufacturers should scrupulously avoid the granting of secret rebates, irrespective of the form assumed. Competition should express itself openly rather than in special and discriminatory form. Among practices violative of this principle which have heretofore prevailed, and the elimination of which is recommended, are the following:

(a) Providing truck service without adequate charge for the same, or reimbursing the dealer or purchaser for trucking costs.

(b) Providing local warehouse facilities or reimbursing the dealer or purchaser for the actual or theoretical cost thereof.

(c) The sale, simultaneously with the sale of mixed fertilizer, of chemicals and materials at special concessions designed to be an inducement to the buyer to purchase mixed fertilizer.

(d) Failure to enforce in good faith the terms of contracts previously made for the sale of fertilizer.

(e) Making up special formulas or using special ingredients in standard formulas without making adequate charge for the cost of such special formulas or special ingredients.

(f) The making of special allowances to buyers for advertising.

(g) Adopting selling methods which, as experience has amply demonstrated, almost always promote secret rebates and concessions and put it out of the power of the manufacturers to control them. Reference is here particularly made to the practice of selling through commission agents and others who are irregularly employed and the compensation of which, without being "loaded" into the price, is measured in terms of quantity sold. Where experience has shown that commission men and like agents customarily resort to split commissions, secret rebates, etc., the manufacturers should sell only through regularly employed, salaried salesmen and agents responsible to and directly controlled by the manufacturers.

(h) Extending credit terms which do not take into account the actual cost of money or of credit.

4. *Avoidance of Unsound Credit Terms*—In certain sections of the country buyers have customarily taken advantage of "open shipments" by taking and using the goods and then refusing to settle on any terms other than those satisfactory to the buyer and often quite different from the terms under which the contract of purchase and sale was made. Where this abuse has prevailed manufacturers should sell only on terms such that, to obtain the bill of lading, the purchasers must make payment in cash or negotiable promissory note for the contract price.

Where delivery is made against promissory note, the note should be made payable at the earliest date consistent with the principle that the fertilizer should be paid for not later than the time when the crop for which the fertilizer is employed is marketed.

5. *No Guaranty of Prices*—Sales should be made at fixed prices and terms accepted in good faith by buyer and seller with the mutual intention of complete performance. The manufacturers should avoid selling under conditions which provide for a reduction of price of goods previously sold in the event of subsequent sales of like goods at lower prices.

The effect of this practice is to apply to goods sold the lowest price which may be quoted by any competitor to any buyer, even though much below the cost of production. This puts the weaker manufacturers at the mercy of the stronger.

6. *Exchange of Statistical Information*—In order that the relations of supply and demand and the statistical conditions existing from time to time in the fertilizer industry may be known, it is proposed to establish a bureau of statistics of the National Fertilizer Association, to which statistical reports shall be made giving information with respect to stocks on hand, production, shipments, average prices realized and such other statistical information as may lawfully be assembled and exchanged, and which shall relate entirely to past and completed transactions. Details as to the foregoing will shortly be elaborated and submitted to the manufacturers.

## Appendix XLIII

### U. S. PRODUCTION OF INSECTICIDAL ARSENIC COMPOUNDS

(From *Census of Mfrs.*)

	1923	1925	1927 <sup>a</sup>	1929 <sup>a</sup>
<i>Calcium Arsenate</i>				
Total production, pounds <sup>b</sup>	34,000,000	18,000,000	—	—
Sales, pounds .....	13,261,233	15,199,387	27,282,326	33,064,426
Value .....	\$1,703,119	\$1,074,960	\$1,665,000	\$1,859,735
No. firms .....	9	8	18	16
<i>Lead Arsenate</i>				
Total production, pounds <sup>b</sup>	19,000,000	20,000,000	—	—
Sales, pounds .....	10,755,137	11,938,032	21,527,838	30,682,379
Value .....	\$2,229,431	\$1,777,552	\$3,190,257	\$3,523,427
No. firms .....	9	13	22	20
<i>Other (Magnesium, Sodium, etc.)<sup>c</sup></i>				
Value .....	\$826,467	\$113,945	\$127,142	\$107,819

<sup>a</sup> Figs. not comparable with 1923 & 1925; <sup>b</sup> "Insecticides produced," from *Min. Ind.*;

<sup>c</sup> In 1923, 1925, & 1926, resp., *Min. Ind.* reported 1,750, 3,500, & 2,500 tons Paris green produced, in 1923 also 1,500,000 gal. sodium arsenite & 4,250 tons miscellaneous arsenic compounds.



## Appendix XLIV

## EARLY WORK ON FURFURAL RESINS

By E. E. Novotny\*

Dr. F. B. LaForge and Gerald H. Mains of the Chemical Division, Department of Agriculture, learned in 1920 that we were interested in the manufacture of furfural resins and that we were commercially using such resins in the manufacture of printing plates and matrices. They approached Durite Plastics with the idea of providing the Department of Agriculture with certain commercial requirements for the production of furfural from corncobs. Durite Plastics purchased and provided what we could call (as a reflection of present policies) a subsidy to the United States Government. With this equipment furfural was produced and used, and Durite Plastics began to consider production on a commercial scale.

Durite Plastics started negotiations with Westinghouse Electric at East Pittsburgh through its engineering staff, headed by a technical man, W. H. Kempton, and Victor H. Beam of the Legal Department. Westinghouse, having tested the phenol-furfural resins and found them highly desirable, contemplated the erection of a plant at a large source of available corncobs. These negotiations were carried out through my associate, J. Stogdell Stokes.

Durite Plastics itself started out without a penny of invested capital and has provided for its increased capacities by plowing back its profits to a large extent.

While a survey was being made with regard to the availability of corncobs, LaForge and Mains carried out work in connection with other annual growth vegetation containing pentosans and determining the furfural yields. Among the next best products were oat hulls, cottonseed hulls, and bagasse fiber as by-products of farm production, and annual growths of kelp and seaweed as available products of marine vegetation.

The production of phenol-furfural resins was not started with a view to competing with phenol-formaldehyde products, but in order to provide a self-controlled resin for use in the production of printing plates. These printing plates had to stand a temperature of over 300° F. in the production of newspaper matrices by the then-used wet flong process. For this reason various phenolic resins such as those of cellulose, carbohydrates, and finally furfural were put into use. The sales of the materials early in 1920 were chiefly to Westinghouse and to some of the older button companies which had formerly processed for themselves composition products out of shellac. Later these resins were also offered for sale to other companies.

Dr. Carl S. Miner of the Miner Laboratories in Chicago was assisted by J. P. Trickey, H. J. Brownlee, and Dr. W. Courtney Wilson of Pyroxylin Products was also an early collaborator. Dr. Miner carried on developments for Quaker Oats Company and it was the desire of this company to make oat hulls more palatable for use as a cattle feed or cattle feed bulking agent. They tried various methods, including the boiling of the oat hulls in the presence of alkalies and acids. In the presence of acids they found that a large part of the pentosans was converted to furfural. Dr. Miner learned through patents issued to me or through the Department of Agriculture that we were interested in furfural utilization and thus a long-lasting acquaintance and a cooperative arrangement sprang up between him and Durite Plastics.

Quaker Oats being a good customer of Stokes & Smith, of which company we were a division at that time, they purchasing packaging machinery from our affiliate, it was natural for us to discuss all work we had done and to come to some definite conclusion as to furfural production, this including also the Westinghouse interests. It was agreed that we give up the idea of manufacturing furfural and take their product for phenol resin manufacture. This condition has continued over all these years, except for the fact

\* To author, Jan. 8, 1947.

that Quaker Oats Company production of furfural is greater than our availability of phenol permits us to consume.

Dr. Miner and his associates also did some work in connection with resins and the resin patent status was established without an interference through mutual confidence and presentation of actual laboratory records showing dates of conception and reduction to practice.

While oat hulls provided the starting point in the production of furfural in this country, these oat hulls were found to be of great value for other purposes and a cheaper source of pentosan-containing vegetable matter is now (1946) being processed to an increasing extent and the particular material now in use in lieu of oat hulls is the good old corncob with which we had originally started.

## Appendix XLV

### NOTES ON EARLY TUNG OIL PROBLEMS

By B. F. Williamson\*

The years you cover was a period that nearly every industry has had to go through. No one could tell you about the handling of the nuts, the fertilization of the trees, the kind of soil the tree grew best on. The Chinaman would cooperate in sending his seed, but he would heat them first. When we asked him what type of soil was best, he told us rocky limestone. We found out that rocky limestone soil is poisonous to the tree.

This oil was always known as China wood oil, and the Chinese product is called that on the market today. Soon after I commenced experimental operation, a Chinaman appeared to find out what it was all about. I asked him why he called it China wood oil. The reply was that they used it for coating and preserving wood. I then asked what they called the trees from which the oil was produced. He said, "Tung-Yu-Shu." I asked, "What does that mean?" He said, "The tung oil tree." So that is where the word started.

The kernel of the nut is a very strong, quick-acting laxative, however the flavor of the meat is very pleasing. One of our Florida citizens planted two trees in his yard for ornaments. His wife thought they would make a nice salad. The salad was made and served. Both husband and wife had a struggle to get to the doctor. However in a few days both were all right and the husband cut down the trees.

A man whose name you seldom see did one of the most important pieces of work. He is Charlie Abbott. He was looking for a subject for his thesis for his M.A., and was sent to me by the University. The tung tree has its Oriental peculiarities, that is, the bud forms in early summer, from which the blossom comes next spring, and the fruit falls in the fall of the next year. This means that if you fertilize for fruit you must go at least two years back. Charlie Abbott took several thousand kernels over a period of a few years and recorded the fruit bud development. After Abbott had finished his work on tung, the citrus industry, which is hundreds of years old, had him do similar work, and I believe he has done the same on pecans. In the meantime we decided that the cluster type, differing from the single type, was the most prolific, and we bred to that type over a period of some eighteen years.

An early question was how to remove the hulls. Having been in the cotton oil business and used that type of huller, I turned to my old friends Bauer Bros. of Springfield, shipping them nuts from the American Grove. Bauer, with me working out the details, built the first huller. They are still building most of the hullers for the tung oil industry. I had had experience with so-called hot pressing with hydraulics, similar to that used in cottonseed and peanuts, and had been in close touch with the extraction of fats with

\* To author, Jan. 23, 1947.

solvents. Knowing how quickly tung oil will polymerize, turning from a liquid to a solid, we gave little thought to the hydraulic system. At Armour I had extracted oil from certain residues of kettle-rendered lard, using one of the first continuous cold presses made by the V. D. Anderson Co. of Cleveland. So the next step was to get the nuts to Anderson, and the Anderson press was the first used by the tung industry. It was put in by L. P. Moore of Benj. Moore & Co.

## Appendix XLVI

### PRODUCTION OF IMPORTANT PIGMENTS IN U. S. (1,000 pounds)

(From *Census of Mfrs.*)

	1923	1925	1927	1929
Total pounds .....	1,309,517	1,608,119	1,773,889	1,918,459
Total value .....	\$91,480	\$103,919	\$105,756	\$116,753
<i>White Lead, Total</i> <sup>a</sup> .....	325,746	327,810	315,390	394,062
Sales .....	140,127	142,930	143,305	150,365
Value .....	\$12,328	\$14,172	\$12,014	\$12,306
<i>Litharge, Total</i> <sup>b</sup> .....	150,214	173,092	163,310	175,832
Sales .....	140,572	167,732	154,622	163,736
Value .....	\$13,241	\$18,022	\$12,816	\$12,965
<i>Red Lead, Total</i> <sup>b</sup> .....	76,074	83,338	78,146	86,042
Sales .....	72,806	80,281	75,286	94,276
Value .....	\$7,286	\$9,146	\$6,961	\$8,174
<i>Zinc Oxide, Sales</i> .....	322,557	318,692	348,211	436,715
Value .....	\$23,471	\$22,741	\$22,286	\$26,933
<i>Lithopone, Sales</i> .....	210,521	246,402	359,759	410,639
Value .....	\$13,002	\$12,185	\$17,164	\$19,270
<i>Iron Oxides, Sales</i> .....	126,908	88,772	108,358	105,627
Value .....	\$3,134	\$2,384	\$3,358	\$3,375
<i>Chrome Yellow, Sales</i> .....	13,238	14,231	14,334	16,399
Value .....	\$2,379	\$2,415	\$2,351	\$2,393
<i>Chrome Orange, Sales</i> .....		1,845	4,652	9,954
Value .....	13,078	\$340	\$751	\$1,450
<i>Chrome Green, Sales</i> .....	\$2,292	12,610	14,114	16,352
Value .....		\$2,231	\$2,460	\$2,603
<i>Prussian Blue, Sales</i> .....	3,138	4,548	4,104	5,359
Value .....	\$1,465	\$1,535	\$1,365	\$1,613
<i>Whiting, Sales</i> .....	—	263,484	221,137	202,208
Value .....	—	\$1,980	\$1,670	\$1,514
<i>Other Dry Colors,</i> <sup>c</sup> Sales.....	90,129	157,051	201,678	211,161
Value .....	\$5,133	\$8,536	\$13,348	\$14,698
<i>Pulp Colors,</i> <sup>d</sup> Sales .....	18,754	16,192	14,407	15,613
Value .....	\$1,244	\$1,381	\$1,302	\$1,390

<sup>a</sup> From *Min. Ind.*, excluding "sublimed white lead"; <sup>b</sup> From *Min. Ind.*; <sup>c</sup> Including barytes; <sup>d</sup> Moist.

U. S. RAYON PRODUCERS, 1929<sup>a</sup>  
(From *Chem. Met. Eng.*)

<i>Company</i>	<i>1st Production</i>	<i>% U. S. Ownership<sup>b</sup></i>	<i>Plants</i>	<i>Process</i>	<i>Current Capacity Mill. Lb.</i>	<i>Total Production Mill. Lb.<sup>c</sup></i>
Acme Rayon Corp. ....	1924	100	Cleveland, O.	Viscose	—	.09
American Bemberg Corp. ....	1927	—49	Johnson City, Tenn.	Cupra	4.3 <sup>c</sup>	2.3
American Chatillon Corp. ....	1929	+51	Rome, Ga.	Viscose	2.5 <sup>c</sup>	1.5
				Acetate	10.3 <sup>d</sup>	—
American Enka Corp. ....	1929	—5	Asheville, N. C.	Viscose	—	1.0
American Glanzstoff Corp. ....	1928	—49	Elizabethton, Tenn.	Viscose	—	3.575
Belanose Corp. ....	1925	100	Rocky Hill, Conn.	Viscose	—	1.7
Celanese Corp. of America ....	1925	—	Amcelle, Md.	Acetate	—	7.0
Delaware Rayon Corp. ....	1927	100	New Castle, Del.	Viscose	—	2.0
Du Pont Rayon Co. ....	1921	100	Old Hickory, Tenn.	Viscose	15.5 <sup>b</sup>	25.1
			Buffalo, N. Y.	Viscose	6.5 <sup>b</sup>	—
			Richmond, Va.	Viscose	4.0 <sup>b</sup>	—
			Waynesboro, Va.	Acetate	1.5 <sup>b</sup>	—
Industrial Rayon Corp. ....	1921	100	Cleveland, O.	Viscose	4.5 <sup>d</sup>	6.5
			Covington, Va.	Viscose	5.5 <sup>d</sup>	—
A. M. Johnson Rayon Mills ....	1929	100	Burlington, N. C.	Viscose	14.4 <sup>d,*</sup>	—
New Bedford Rayon Co. ....	1929	100	New Bedford, Mass.	Viscose	—	0.4
Skenandoa Rayon Corp. ....	1928	100	Utica, N. Y.	Viscose	—	1.35
Tubize Artificial Silk Co. ....	1921	95	Hopewell, Va.	Nitro	—	11.0
Viscose Co. ....	1911	15	Marcus Hook, Pa.	Viscose	25.0 <sup>b</sup>	66.0
			Lewiston, Pa.	Viscose	17.0 <sup>b</sup>	—
			Parkersburg, W. Va.	Viscose	17.0 <sup>b</sup>	—
			Roanoke, Va.	Viscose	17.0 <sup>b</sup>	—
			Meadville, Pa.	Acetate	5.0 <sup>b</sup>	—
			Nitro, W. Va.	Linters	—	—

<sup>a</sup> Rosland Corp. (Cupra) & Napon Rayon Corp. (Cupra) inactive; Furness Corp. (Cupra) & Woonsocket Rayon Corp. (Viscose) experimental; <sup>b</sup> Independent estimate; <sup>c</sup> *Textile World* estimate; <sup>d</sup> Avram, *Rayon Industry*; \* Planned.

## Appendix XLVIII

## ESTIMATED HEAVY CHEMICAL CONSUMPTION IN SOME CHEMICAL ENGINEERING INDUSTRIES

[From *Chem. Met. Eng.* 34, 585 (1927).]

<i>Heavy Chemicals</i>	<i>Food Products</i>	<i>Glass &amp; Ceramics</i>	<i>Leather</i>	<i>Pulp &amp; Paper</i>	<i>Rubber</i>	<i>Soap</i>
Acetic acid, 28%, short tons .....	—	—	4,000	—	—	—
Alcohol, denatured, wine gallons .....	1,500,000	—	2,000,000	—	1,500,000	500,000
Aluminum sulfate, tons .....	500	250	500	100,000	—	—
Ammonia, short tons of N .....	—	—	—	—	—	250
Arsenic, short tons .....	—	3,500	—	—	—	—
Chlorine, liquid, short tons .....	—	—	—	32,500	—	—
Hydrochloric acid, 20° Bé., short tons.....	7,000	5,000	5,000	—	—	7,000
Lime, short tons .....	20,000	500,000	60,000	330,000	3,000	40,000
Oxalic acid, pounds .....	—	—	200,000	—	—	—
Salt, short tons .....	4,150,000	50,000	100,000	50,000	—	100,000
Soda ash, short tons .....	500	585,000	2,000	75,000	—	200,000
Sodium bichromate, short tons .....	—	—	11,600	—	—	—
Sodium hydroxide, short tons .....	—	—	1,000	9,000	17,000	112,000
Sodium nitrate, long tons .....	5,000	500	—	—	—	—
Sodium silicate, 40° Bé., short tons .....	—	2,000	—	10,000	—	83,000
Sodium sulfate, short tons .....	—	45,000	—	103,000	—	2,000
Sulfur, long tons .....	3,000	—	—	260,000	25,000	—
Sulfuric acid, 50° Bé., short tons .....	2,000	500	5,000	500	25,000	5,000
Zinc oxide, short tons .....	—	2,500	—	—	78,000	500

## Appendix XLIX

## AMERICAN CHEMICAL SOCIETY, 1923-29

*Presidents:* 1923, E. C. Franklin; 1924, L. H. Baekeland; 1925-26, J. F. Norris; 1927, G. D. Rosengarten; 1928, S. W. Parr; 1929, Irving Langmuir. *Secretary:* 1907-45, C. L. Parsons. *Treasurer:* 1919-31, J. E. Teeple. *Directors:* 1923, E. C. Franklin; 1923-24, W. R. Whitney, M. C. Whitaker; 1923-25, William Hoskins; 1923-26, H. P. Talbot; 1923-27, G. D. Rosengarten; 1923-29, C. L. Parsons, W. D. Bancroft, J. E. Teeple; 1924, L. H. Baekeland; 1925-29, W. D. Bigelow, E. C. Franklin, J. F. Norris; 1926-29, S. W. Parr; 1927-29, C. L. Reese; 1928-29, F. C. Whitmore; 1929, Irving Langmuir. *Editors of Publications:* *Journal of the American Chemical Society*, 1918-47, A. B. Lamb; *Chemical Abstracts*, 1915-47, E. J. Crane; *Industrial & Engineering Chemistry*, 1922-42, H. E. Howe.

## AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, 1923-29

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## MANUFACTURING CHEMISTS' ASSOCIATION, 1923-29

*Presidents:* 1922-23, C. L. Reese; 1923-26, E. H. Hooker; 1926-29, Henry Howard; 1929-33, Lamot du Pont. *Vice-Presidents:* 1922-25, C. W. Miller, M. C. Whitaker; 1925-29, H. A. Galt; 1925-30, W. D. Huntington. *Secretary:* 1922-31, J. I. Tierney; *Treasurers:* 1922-27, S. W. Wilder; 1927-31, Philip Schleussner. *Executive Committee:* 1922-23, E. M. Allen, T. M. Rianhard; 1922-24, R. T. Baldwin, Lancaster Morgan; 1922-25, H. H. Dow; 1922-26, Henry Howard; 1922-27, A. G. Rosengarten; 1923-31, W. H. Bower, C. L. Reese; 1924-25, G. G. Ackerson; 1924-29, H. F. Atherton; 1925-26, W. F. Barrett; 1925-38, C. W. Millard; 1926-27, Philip Schleussner; 1926-42, H. L. Derby; 1927-31, S. W. Wilder; 1927-33, G. W. Merck; 1929-31, J. A. Rafferty.

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## Appendix XLIX

## AMERICAN CHEMICAL SOCIETY, 1923-29

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## BOOK TITLES

- Adams, Henry. *The Degradation of the Democratic Dogma*. N. Y., Macmillan, 1919.
- After 30 Years: Commemorating the 30th Anniversary of the Foundation of the American Cyanamid Company, 1907-37*. N. Y., American Cyanamid, 1938.
- Alico, John. *Introduction to Magnesium and Its Alloys*. Chicago, Ziff-Davis, 1946.
- Allen, J. Fenwick. *Some Founders of the Chemical Industry*. London, Sherratt & Hughes, 1906.
- Anderson, Benjamin M., Jr. *The Value of Money*. N. Y., Smith, 1936.
- Annual Survey of American Chemistry*. N. Y., Chem. Catalog, 1925-35, 6 v.
- Anthony, Arthur B. *Economic and Social Problems of the Machine Age*. Los Angeles, U. Southern Calif., 1930.
- Archer, Gleason L. *History of Radio to 1926*. N. Y., Ann. Hist. Soc., 1938.
- Atkins, Willard E., ed. *Economic Behavior*. Boston, Houghton Mifflin, 1931, 2 v.
- Austin, Leonard S. *The Metallurgy of Common Metals*. 6th ed., rev. N. Y., Wiley, 1926.
- Avram, Mois H. *The Rayon Industry*. 2d ed. N. Y., Van Nostrand, 1929.
- Bailey, Alton E. *Industrial Oil and Fat Products*. N. Y., Interscience, 1945.
- Bain, H. Foster. *Ores and Industry in the Far East*. N. Y., Council For. Rela-tions. 1927.
- Barnes, Harry E. *World Politics in Modern Civilization*. N. Y., Knopf, 1930.
- Bauer, John, and Nathaniel Gold. *The Electric Power Industry*. N. Y., Harper, 1939.
- Beard, Charles A., and Mary R. Beard. *The Rise of American Civilization*. N. Y., Macmillan, 1933.
- Beckman, Theodore N., and Herman C. Nolen. *The Chain Store Problem*. N. Y., McGraw-Hill, 1938.
- Bell, Harold S. *American Petroleum Refining*. 2d ed. N. Y., Van Nostrand, 1930.
- Belloc, Hilaire. *The Highway and Its Vehicles*. London, Studio, 1926.
- Bennett, E. F. *A Review of Driers and Drying*. N. Y., Chem. Pub. Co., 1941.
- Bergman, M. L. *Manufacturing Processes*. N. Y., Wiley, 1942.
- Bishop, Avard L. *Outlines of American Foreign Commerce*. Boston, Ginn, 1923.
- Bogart, Ernest L. *Economic History of the American People*. 2d ed. N. Y., Longmans, Green, 1935.
- , and Charles E. Landon. *Modern Industry*. 2d ed. N. Y., Longmans, Green, 1936.



- Borkin, Joseph, and Charles A. Welsh. *Germany's Master Plan*. N. Y., Duell, Sloan & Pearce, 1943.
- Borth, Christy. *Pioneers of Plenty*. N. Y., Bobbs-Merrill, 1939.
- Boucke, O. Fred. *Laissez Faire and After*. N. Y., Crowell, 1932.
- *Principles of Economics*. N. Y., Macmillan, 1925, 2 v.
- Bowden, Witt. *Industrial History of the United States*. N. Y., Adelphi Co., 1930.
- Boylston, Herbert M. *An Introduction to the Metallurgy of Iron and Steel*. 2d ed. N. Y., Wiley, 1936.
- Braake, Alex L. ter. *Mining in the Netherlands East Indies*. N. Y., Inst. Pacific Relations, 1944.
- Brady, Robert A. *Business as a System of Power*. N. Y., Columbia U. Press, 1943.
- *The Rationalization Movement in German Industry*. Berkeley, Calif., U. Calif. Press, 1933.
- Brandeis, Louis D. *Business—a Profession*. Boston, Small, Maynard, 1925.
- Broderick, John T. *Forty Years with General Electric*. Albany, Fort Orange Press, 1929.
- Bronson, L. G. *Cartels and International Patent Administration*. Wash., D. C., Library of Congress, 1944 (*Pub. Affairs Bull. No. 26*).
- Brookings, Robert S. *Economic Democracy*. N. Y., Macmillan, 1929.
- Brooks, Benjamin T. *The Chemistry of Non-Benzenoid Hydrocarbons and Their Simple Derivatives*. N. Y., Chem. Catalog, 1922.
- Brown, Bruce K., and Francis M. Crawford. *A Survey of Nitrocellulose Lacquer*. N. Y., Chem. Catalog, 1928.
- Brown, Nelson C. *Forest Products, Their Manufacture and Use*. 2d ed., rev. N. Y., Wiley, 1927.
- [Browne, H. F., and others.] *Wages and Hours in American Industry*. N. Y., Nat. Ind. Conference Bd., 1925.
- Bruck, Werner F. *Social and Economic History of Germany from William II to Hitler, 1888-1938*. London, Oxford U. Press, 1938.
- Bücher, Karl. *Industrial Evolution*. Tr. from 3d German ed by S. Morley Wickett. N. Y., Holt, 1901.
- Bunbury, Hugh M., and Alexander Davidson. *Industrial Applications of Coal-Tar Products*. N. Y., Van Nostrand, 1925.
- Burlingame, William R. *March of the Iron Men*. N. Y., Scribner's, 1938.
- Cain, John C., and Jocelyn F. Thorpe. *The Synthetic Dyestuffs and Intermediates from Which They are Derived*. 7th ed. rev. by Thorpe and Reginald P. Linstead. London, Griffin, 1933.
- Carlton, Frank T. *Labor Problems*. Boston, Heath, 1933.
- Carman, Harry J. *Social and Economic History of the United States*. Boston, Heath, 1930, 2 v.
- Carver, Thomas N. *The Present Economic Revolution in the United States*. Boston, Little, Brown, 1925.
- Chamberlain, Joseph S., ed. *Chemistry in Agriculture*. N. Y., Chem. Foundation, 1926.
- Chatfield, Herbert W. *Varnish Constituents*. N. Y., Interscience, 1944.
- Chemical Progress in the South*. Comp. & ed. by Nat. Res. Council. N. Y., Chem. Foundation, 1930.
- Chen, Ko Kuei, and Carl F. Schmidt. *Ephedrine and Related Substances*. Baltimore, Williams & Wilkins, 1930.

- Churchill, Winston L. S. *The World Crisis*. N. Y., Scribner's, 1931.
- Clark, Fred E. *Readings in Marketing*. Rev. ed. N. Y., Macmillan, 1933.
- Clark, John M. *Demobilization of Wartime Economic Controls*. N. Y., McGraw-Hill, 1944.
- *The Costs of the World War to the American People*. New Haven, Yale U. Press, 1932.
- Clark, Victor S. *History of Manufacturers in the United States*. N. Y., McGraw-Hill, 1929, 3 v.
- Cochran, Thomas C., and William Miller. *The Age of Enterprise*. N. Y., Macmillan, 1942.
- Collings, Gilbert H. *Commercial Fertilizers*. 3d ed. Phila., Blakiston, 1941.
- Corson, Michael G. *Aluminum: The Metal and Its Alloys*. N. Y., Van Nostrand, 1926.
- Creighton, H. Jermain, and W. A. Koehler. *Principles and Applications of Electrochemistry*. 3d ed. N. Y., Wiley, 1935, 2 v.
- Cressy, Edward. *Discovery and Inventions of the Twentieth Century*. 3d ed. N. Y., Dutton, 1930.
- Crowther, Samuel. *America Self-Contained*. Garden City, N. Y., Doubleday, Doran, 1933.
- Culbertson, William S. *International Economic Policies*. N. Y., Appleton, 1925.
- Cummins, Earl E. *The Labor Problem in the United States*. N. Y., Van Nostrand, 1932.
- Curtis, Harry A. *Fixed Nitrogen*. N. Y., Chem. Catalog, 1932.
- Cushman, Allerton S. *Chemistry and Civilization*. 2d ed. N. Y., Dutton, 1925.
- Daggett, Stuart. *Principles of Inland Transportation*. N. Y., Harper, 1928.
- Darrah, Juanita E., comp. *Modern Baking Powder*. Chicago, Commonwealth Press, 1927.
- Davis, Watson. *The Story of Copper*. N. Y., Century, 1924.
- , ed. *The Advance of Science*. N. Y., Doubleday, 1934.
- Dean, Harry K. *Utilization of Fats*. N. Y., Chem. Pub. Co., 1938.
- [Derby, Harry L., and others.] *The Traffic Library*. Chicago, Am. Commerce Assoc., 1916.
- Dewey, Davis R. *Financial History of the United States*. 11th ed. N. Y., Longmans, Green, 1931.
- Die Deutsche Kaliindustrie*. 3d ed. Berlin, Mittler & Sohn, 1929.
- Dow, Grove S. *Society and Its Problems*. 3d ed., rev. N. Y., Crowell, 1929.
- Driver, J. E., and G. E. Trease. *The Chemistry of Crude Drugs*. N. Y., Longmans, Green, 1928.
- DuBois, John H. *Plastics*. Chicago, Am. Tech. Soc., 1942.
- Duffus, Robert L. *The Valley and Its People: A Portrait of TVA*. N. Y., Knopf, 1944.
- Dunstan, Albert E., and others, ed. *The Petroleum Industry*. N. Y., Inst. Petr. Tech., 1922.
- *The Science of Petroleum*. London, Oxford U. Press, 1938, 4 v.
- Dutton, William S. *Du Pont: One-Hundred and Forty Years*. N. Y., Scribner's, 1942.
- Edie, Lionel S., ed. *Current Social and Industrial Forces*. N. Y., Boni, 1920.
- Edwards, Junius D., Francis C. Frary, and Zay Jeffries. *The Aluminum Industry*. N. Y., McGraw-Hill, 1930, 2 v.
- Egloff, Gustav. *The Reactions of Pure Hydrocarbons*. N. Y., Reinhold, 1937.

- Ellis, Carleton. *The Chemistry of Petroleum Derivatives*. N. Y., Reinhold, 1934-37, 2 v.  
— *The Chemistry of Synthetic Resins*. N. Y., Reinhold, 1935, 2 v.  
Ellsworth, Paul T. *Chile, An Economy in Transition*. N. Y., Macmillan, 1945.  
Epstein, Ralph C. *The Automobile Industry*. Chicago, Shaw, 1928.  
Ernst, Frank A. *Fixation of Atmospheric Nitrogen*. N. Y., Van Nostrand, 1928.
- Fabricant, Solomon. *The Output of Manufacturing Industries, 1899-1937*. N. Y., Nat. Bur. Econ. Res., 1940.  
Fairlie, Andrew M. *Sulphuric Acid Manufacture*. N. Y., Reinhold, 1936.  
Faloon, Dalton B. *Zinc Oxide*. N. Y., Van Nostrand, 1925.  
Farnham, Dwight T., and others. *Profitable Science in Industry*. N. Y., Macmillan, 1925.  
Farrell, Hugh. *What Price Progress?* N. Y., Putnam's, 1926.  
Faulkner, Harold U. *The Quest for Social Justice, 1898-1914*. N. Y., Macmillan, 1931.  
Findlay, Alexander. *A Hundred Years of Chemistry*. N. Y., Macmillan, 1937.  
Ford, Henry, and Samuel Crowther. *My Life and Work*. New ed. Garden City, N. Y., Doubleday, Page, 1922.  
Fraser, Herbert F. *Foreign Trade and World Politics*. N. Y., Knopf, 1926.  
Fraser, Lindley M. *Germany Between Two Wars*. N. Y., Oxford U. Press, 1945.  
Frear, Donald E. H. *Chemistry of Insecticides and Fungicides*. N. Y., Van Nostrand, 1942.  
Frederick, Justus G. *Modern Industrial Consolidation*. N. Y., Frank-Maurice, 1926.  
Freundlich, Herbert. *The Chemistry of Rubber*. London, Methuen, 1935.  
Furniss, Edgar S., and Lawrence R. Guild. *Labor Problems*. Boston, Houghton Mifflin, 1925.
- Gamble's Naval Stores Year Book*. Savannah, Ga., annual.  
Gardner, Walter M., ed. *The British Coal-Tar Industry*. London, Williams & Norgate, 1915.  
Garrett, Garet. *A Time Is Born*. N. Y., Pantheon, 1944.  
— *The American Omen*. N. Y., Dutton, 1928.  
Geer, William C. *The Reign of Rubber*. N. Y., Century, 1922.  
Gibson, Charles R. *The Motor Car and Its Story*. Phila., Lippincott, 1927.  
Glaeser, Martin G. *Outlines of Public Utility Economics*. N. Y., Macmillan, 1927.  
Glass, Carter. *An Adventure in Constructive Finance*. Garden City, N. Y., Doubleday, Page, 1927.  
Glover, John G., and William B. Cornell. *The Development of American Industries*. Rev. ed. N. Y., Prentice-Hall, 1941.  
Gordon, Robert A. *Business Leadership in the Large Corporation*. Wash., D. C., Brookings Inst., 1945.  
Gras, N. S. B. *Business and Capitalism*. N. Y., Crofts, 1939.  
— *Industrial Evolution*. Cambridge, Mass., Harvard U. Press, 1930.  
Greer, Guy. *The Ruhr-Lorraine Industrial Problem*. N. Y., Macmillan, 1925.  
Groggins, Philip H. *Aniline and Its Derivatives*. N. Y., Van Nostrand, 1924.  
— *Unit Processes in Organic Synthesis*. 2d ed. N. Y., McGraw-Hill, 1938.  
Gruse, William A., and Donald R. Stevens. *The Chemical Technology of Petroleum*. 2d ed. N. Y., McGraw-Hill, 1942.

- Hale, Harrison. *American Chemistry*. 2d ed. N. Y., Van Nostrand, 1928.
- Hale, William J. *Chemistry Triumphant*. Baltimore, Williams & Wilkins, 1932.
- *Prosperity Beckons*. Boston, Stratford, 1936.
- Hammond, John W. *Charles Proteus Steimmetz*. N. Y., Century, 1924.
- Hamson, C. J. *Patent Rights for Scientific Discoveries*. Indianapolis, Bobbs-Merrill, 1930.
- Haney, Lewis H. *Business Organization and Combination*. 3d ed. N. Y., Macmillan, 1934.
- Hard, Arnold H. *The Romance of Rayon*. Manchester, Whittaker & Robinson, 1933.
- Harrow, Benjamin, and Carl P. Sherwin, ed. *Textbook of Biochemistry*. Phila., Saunders, 1935.
- Harvey-Gibson, Robert J. *Two Thousand Years of Science*. N. Y., Macmillan, 1929.
- Haskin, Frederic J. *American Government Today*. N. Y., Grosset, 1935.
- Hauser, Ernst A. *Latex*. Tr. by W. J. Kelly, with Patent Review by Carl Boehm von Boernegg. N. Y., Chem. Catalog, 1930.
- Hawkins, R. R. *Scientific, Medical, and Technical Books Published in the U. S. A., 1930-1944*. Wash., D. C., Nat. Res. Council, 1946.
- Hawley, Lee F., and Louis E. Wise. *The Chemistry of Wood*. N. Y., Chem. Catalog, 1926.
- Hayes, H. Gordon. *Our Economic System*. N. Y., Holt, 1928, 2 v.
- Haynes, Frederick E. *Social Politics in the United States*. Boston, Houghton Mifflin, 1924.
- Haynes, Roy A. *Prohibition Inside Out*. Garden City, N. Y., Doubleday, Page, 1923.
- Haynes, Williams. *Chemical Economics*. N. Y., Van Nostrand, 1933.
- *Chromium Chemicals*. N. Y., Mutual Chemical Co., 1941.
- *Men, Money and Molecules*. N. Y., Doubleday, 1936.
- *Southern Horizons*. N. Y., Van Nostrand, 1946.
- *The Chemical Front*. N. Y., Knopf, 1943.
- *The Stone That Burns*. N. Y., Van Nostrand, 1942.
- *This Chemical Age*. 2d ed. N. Y., Knopf, 1942.
- , and Ernst A. Hauser. *Rationed Rubber*. N. Y., Knopf, 1942.
- Haynes Chemicals and Raw Materials Directory Service*. Newark, N. J., Chemic Press, 1939.
- Heckel, George B. *The Paint Industry*. St. Louis, Am. Paint J. Co., 1931.
- Hempel, Edward H. *The Economics of Chemical Industries*. N. Y., Wiley, 1939.
- Hesse, Erich. *Narcotics and Drug Addiction*. Tr. by Frank Gaynor. N. Y., Philosophical Library, 1946.
- Heuser, Emil. *The Chemistry of Cellulose*. N. Y., Wiley, 1944.
- Hodgins, Eric, and F. Alexander Magoun. *Behemoth: The Story of Power*. Garden City, N. Y., Doubleday, Doran, 1932.
- Holland, Maurice C., and Henry F. Pringle. *Industrial Explorers*. N. Y., Harper, 1928.
- Holmes, Harry N. *Fifty Years of Industrial Aluminum*. Oberlin, O., 1937.
- Hotchkiss, George B. *Milestones of Marketing*. N. Y., Macmillan, 1938.
- Hou, Te-Pang. *Manufacture of Soda*. 2d ed. N. Y., Reinhold, 1942.
- Hourwich, Isaac A. *Immigration and Labor*. 2d ed., rev. N. Y., Viking, 1922.
- Howard, Robert W. *Two Billion Acre Farm*. Garden City, N. Y., Doubleday, 1945.

- Humphrey, Edward F. *An Economic History of the United States*. N. Y., Century, 1931.
- Hunter, Dard. *Papermaking Through Eighteen Centuries*. N. Y., Rudge, 1930.
- Hutton, Frederick R. *The Gas-Engine*. 3d ed., rev. N. Y., Wiley, 1908.
- Institute of American Meat Packers. *The Packing Industry*. Chicago, U. Chicago Press, 1924.
- Jamieson, George S. *Vegetable Fats and Oils*. 2d ed. N. Y., Reinhold, 1943.
- Jeffrey, Edward C. *Coal and Civilization*. N. Y., Macmillan, 1925.
- Jennings, Walter W. *A History of Economic Progress in the United States*. N. Y., Crowell, 1926.
- *A History of the Economic and Social Progress of the American People*. Cincinnati, South-Western Pub. Co., 1937.
- Jenkins, Glenn L., and Walter H. Hartung. *The Chemistry of Organic Medicinal Products*. 2d ed. N. Y., Wiley, 1943.
- Jenks, Jeremiah W., and W. Jett Lauck. *The Immigration Problem*. 6th ed., rev. & enl. by Rufus D. Smith. N. Y., Funk & Wagnalls, 1926.
- Jones, Eliot. *The Trust Problem in the United States*. N. Y., Macmillan, 1921.
- , and Truman C. Bigham. *Principles of Public Utilities*. N. Y., Macmillan, 1931.
- Kaempffert, Waldemar B., ed. *A Popular History of American Invention*. N. Y., Scribner's, 1924, 2 v.
- Keezer, Dexter M., and Stack May. *The Public Control of Business*. N. Y., Harper, 1930.
- Keir, R. Malcolm. *Manufacturing Industries in America*. N. Y., Ronald Press, 1920.
- Kelly, Fred C. *One Thing Leads to Another*. Boston, Houghton Mifflin, 1936.
- Kemmerer, Edwin W. *Gold and the Gold Standard*. N. Y., McGraw-Hill, 1944.
- *The A B C of the Federal Reserve System*. 9th ed. Princeton, N. J., Princeton Press, 1932.
- Kerwin, Jerome G. *The Federal Water Power Legislation*. N. Y., Columbia U. Press, 1926.
- Keynes, John M. *The Economic Consequences of the Peace*. N. Y., Harcourt, Brace, 1920.
- Killough, Hugh B., and Lucy W. Killough. *Raw Materials of Industrialism*. N. Y., Crowell, 1929.
- King, Clyde L., and Frank A. Tichenor, ed. *The Motion Picture in Its Economic and Social Aspects*. Phila., Am. Acad. Political & Social Sciences, 1926.
- Kingzett's Chemical Encyclopaedia*. 6th ed. rev. & ed. by Ralph K. Strong. London, Ballière, Tindall & Cox, 1940.
- Klar, M. *The Technology of Wood Distillation*. Tr. from German by Alexander Rule. N. Y., Van Nostrand, 1925.
- Knorr, Klaus E. *Tin Under Control*. Stanford, Calif., Stanford U. Food Res. Inst., 1945.
- Koehler, Arthur. *Properties and Uses of Wood*. N. Y., McGraw-Hill, 1924.
- Kohlsaat, Herman H. *From McKinley to Harding*. N. Y., Scribner's, 1923.
- Kreps, Theodore J. *The Economics of the Sulfuric Acid Industry*. Stanford, Calif., Stanford U. Press, 1938.

- Kuznets, Simon S. *Secular Movements in Production and Prices*. Boston, Houghton Mifflin, 1930.
- Laidler, Harry W. *Concentration of Control in American Industry*. N. Y., Crowell, 1931.
- Landis, Walter S. *Your Servant the Molecule*. N. Y., Macmillan, 1944.
- Laughlin, J. Laurence. *The Federal Reserve Act*. N. Y., Macmillan, 1933.
- Laury, Napoleon L. *Hydrochloric Acid and Sodium Sulfate*. N. Y., Chem. Catalog, 1927.
- Lawrence, Joseph S. *Stabilization of Prices*. N. Y., Macmillan, 1928.
- Levy, Hermann. *Industrial Germany*. Cambridge, Cambridge U. Press, 1935.
- *Monopolies, Cartels and Trusts in British Industry*. 2d ed. London, Macmillan, 1927.
- *National Health Insurance*. N. Y., Macmillan, 1945.
- Liefmann, Robert. *Cartels, Concerns and Trusts*. Tr. by D. H. Macgregor. N. Y., Dutton, 1932.
- Lilley, Ernest R. *The Oil Industry*. N. Y., Van Nostrand, 1925.
- Lincoln, Edmond E. *Applied Business Finance*. Chicago, Shaw, 1923.
- Lippincott, Isaac. *Economic Development of the United States*. N. Y., Appleton, 1927.
- *What the Farmer Needs*. N. Y., Appleton, 1928.
- Lowry, Homer H., ed. *The Chemistry of Coal Utilization*. N. Y., Wiley, 1945, 2 v.
- Lunge, Georg. *Handbuch der Schwefelsäurefabrikation*. 4th ed. by Bruno Waeser. Braunschweig, Vieweg & Sohn, 1930, 3 v.
- Lynd, Robert S. *Middletown*. N. Y., Harcourt, Brace, 1929.
- Lyon, Liverett S. *Hand-to-Mouth Buying*. Wash., D. C., Brookings Inst., 1929.
- MacDowell, Charles H. *The Problems of Muscle Shoals*. Chicago, 1925.
- MacInnes, Duncan A. *The Principles of Electrochemistry*. N. Y., Reinhold, 1939.
- McLaughlin, George D., and Edwin R. Theis. *The Chemistry of Leather Manufacture*. N. Y., Reinhold, 1945.
- McMillen, Wheeler. *New Riches from the Soil: The Progress of Chemurgy*. N. Y., Van Nostrand, 1946.
- McVey, Frank L. *Modern Industrialism*. 2d ed. N. Y., Appleton, 1923.
- Macedo Soares, José Carlos de. *Rubber*. Tr. by Philip Schidrowitz. N. Y., Smith, 1930.
- Malin, James C. *United States After the World War*. Boston, Ginn, 1930.
- Maltbie, Birdsley L. *A Quarter Century of Progress in the Manufacture of Pharmaceuticals*. N. Y., Am. Pharm. Mfrs. Assoc., 1937.
- Manchester, Harland F. *New World of Machines*. N. Y., Random, 1945.
- Mantell, Charles L. *Industrial Carbon*. N. Y., Van Nostrand, 1928.
- *Industrial Electrochemistry*. 2d ed. N. Y., McGraw-Hill, 1940.
- *Tin*. N. Y., Chem. Catalog, 1929.
- Marchionna, Frederick. *Latex and Its Industrial Applications*. N. Y., Rubber Age, 1933-37, 3 v.
- Martin, Robert F. *International Raw Commodity Price Control*. N. Y., Nat. Ind. Conference Bd., 1937.
- Mason, J. Philip, and Joseph F. Manning. *Technology of Plastics and Resins*. N. Y., Van Nostrand, 1945.

- Mathewson, Champion H., ed. *Modern Uses of Non-Ferrous Metals*. N. Y., Am. Inst. Min. Met. Engrs., 1935.
- Matthews, Joseph M. *The Textile Fibers*. 4th ed. N. Y., Wiley, 1924.
- Mattiello, Joseph J., ed. *Protective and Decorative Coatings*. N. Y., Wiley, 1943, 5 v.
- Mauersberger, Herbert R., and E. W. K. Schwarz. *Rayon and Staple Fiber Handbook*. 3d ed. N. Y., Rayon Handbook, 1939.
- Maxey, Chester C. *Urban Democracy*. Boston, Heath, 1929.
- Mead, Edward S., and Karl W. H. Scholz. *Rudiments of Business Finance*. N. Y., Appleton, 1926.
- Merry, Ernest W. *The Chrome Tanning Process*. London, Harvey, 1936.
- Merz, Charles. *And Then Came Ford*. Garden City, N. Y., Doubleday, 1929.
- Miall, Stephen. *A History of the British Chemical Industry*. London, Benn, 1931.
- Michels, Rudolf K. *Cartels, Combines and Trusts in Post-War Germany*. N. Y., Columbia U. Press, 1928.
- Miller, Sidney L. *Inland Transportation*. N. Y., McGraw-Hill, 1933.
- Millikan, Robert A. *Science and the New Civilization*. N. Y., Scribner's, 1930.
- Mills, Frederick C. *The Behavior of Prices*. N. Y., Nat. Bur. Econ. Res., 1927.
- Mitchell, Broadus, and George S. Mitchell. *The Industrial Revolution in the South*. Baltimore, Johns Hopkins Press, 1930.
- Mitchell, Wesley C. *Business Cycles*. N. Y., Nat. Bur. Econ. Res., 1927.
- Monier-Williams, Gordon W. *Power Alcohol*. London, Frowde, 1922.
- Morgan, Sir Gilbert, and David D. Pratt. *British Chemical Industry*. London, Arnold, 1938.
- Mottram, Ralph H. *A History of Financial Speculation*. Boston, Little, Brown, 1929.
- Mumford, Lewis. *The Condition of Man*. N. Y., Harcourt, Brace, 1944.
- Naunton, W. J. S. *Synthetic Rubber*. London, Macmillan, 1937.
- Nearing, Scott, and Joseph Freeman. *Dollar Diplomacy*. N. Y., Huebsch & Viking Press, 1925.
- Nieuwland, Julius A., and R. R. Vogt. *The Chemistry of Acetylene*. N. Y., Reinhold, 1945.
- Noble, Royce J. *Latex in Industry*. N. Y., Rubber Age, 1936.
- Nystrom, Paul H. *Economics of Retailing*. 3d ed. rev. & enl. N. Y., Ronald Press, 1932.
- Ogg, Frederic C. *Economic Development of Modern Europe*. N. Y., Macmillan, 1926.
- Parkins, Almon E., and J. R. Whitaker, ed. *Our Natural Resources and Their Conservation*. N. Y., Wiley, 1936.
- Parry, Ernest J. *Cyclopedia of Perfumery*. Phila., Blakiston, 1925, 2 v.
- *The Chemistry of Essential Oils and Artificial Perfumes*. 4th ed. N. Y., Van Nostrand, 1923, 2 v.
- Partington, James R. *The Alkali Industry*. 2d ed. N. Y., Van Nostrand, 1925.
- Patterson, Albert M. *The Reparation Dyestuff Situation*. Pittsfield, Mass., Sun Prtg. Co., 1922.
- Peattie, Donald C. *Cargoes and Harvests*. N. Y., Appleton, 1926.
- Perry, John D., ed. *Chemical Engineers' Handbook*. 2d ed. N. Y., McGraw-Hill, 1941.

- Perry, Ralph B. *Puritanism and Democracy*. N. Y., Vanguard, 1944.
- Pigou, Arthur C. *Industrial Fluctuations*. London, Macmillan, 1927.
- Poucher, William A. *Perfumes, Cosmetics & Soaps*. N. Y., Van Nostrand, 1936, 3 v.
- Pound, Arthur. *Salt of the Earth: Story of Capt. J. B. Ford and Michigan Alkali Co., 1890-1940*. Boston, Atlantic Monthly, 1940.
- *The Iron Man in Industry*. Boston, Houghton Mifflin, 1922.
- *The Turning Wheel: The Story of General Motors through 25 Years, 1908-1933*. Garden City, N. Y., Doubleday, 1934.
- Prentiss, Augustin M. *Chemicals in War*. N. Y., McGraw-Hill, 1937.
- Přibram, Karl. *Cartel Problems*. Wash., D. C., Brookings Inst., 1935.
- Queeny, Edgar M. *The Spirit of Enterprise*. N. Y., Scribner's, 1943.
- Quinn, Elton L., and Charles L. Jones. *Carbon Dioxide*. N. Y., Reinhold, 1936.
- Rahm, Louis F. *Plastic Molding*. N. Y., McGraw-Hill, 1933.
- Ramsaye, Terry. *A Million and One Nights: A History of the Motion Picture*. N. Y., Simon & Schuster, 1926, 2 v.
- Read, Thomas T. *Our Mineral Civilization*. Baltimore, Williams & Wilkins, 1932.
- Read, William T. *Industrial Chemistry*. 3d ed. N. Y., Wiley, 1943.
- Recent Economic Changes in the U. S.* (Conference on Unemployment, Wash., D. C., 1921). N. Y., McGraw-Hill, 1929, 2 v.
- Redman, L. V., and A. V. H. Mory. *The Romance of Research*. Baltimore, Williams & Wilkins, 1933.
- Reeve, Joseph E. *Monetary Reform Movements*. Wash., D. C., Am. Council Public Affairs, 1943.
- Richter, Victor von. *Organic Chemistry*. Tr. & rev. from 12th German ed. by Eric N. Allott. Phila., Blakiston, 1934.
- Rickard, Thomas A. *A History of American Mining*. N. Y., McGraw-Hill, 1932.
- Riegel, Emil R. *Industrial Chemistry*. 2d ed. N. Y., Reinhold, 1933.
- Ripley, William Z. *Main Street and Wall Street*. Boston, Little, Brown, 1927.
- Rogers' Industrial Chemistry*. 5th ed. N. Y., Van Nostrand, 1931, 2 v.
- 6th ed. by Clifford C. Furnas. N. Y., Van Nostrand, 1942, 2 v.
- Rourke, Constance M. *The Roots of American Culture and Other Essays*. N. Y., Harcourt, Brace, 1942.
- Sachanen, Alexander N. *The Chemical Constituents of Petroleum*. N. Y., Reinhold, 1945.
- Sagarin, Edward. *The Science and Art of Perfumery*. N. Y., McGraw-Hill, 1945.
- Sanderson, E. Dwight. *Insect Pests of Farm, Garden, and Orchard*. 3d ed. rev. & enl. by Leonard M. Peairs. N. Y., Wiley, 1931.
- Scanlon, Helen L., comp. *Enemy Property in World War I: A Bibliography*. Wash., D. C., Carnegie Endowment Internat. Peace, 1944.
- Schlesinger, Arthur M. *New Viewpoints in American History*. N. Y., Macmillan, 1922.
- *Political and Social Growth of the United States, 1852-1933*. 3d ed. N. Y., Macmillan, 1941.
- Schwarz, Eugene W. K., and Herbert R. Mauersberger. *Rayon and Staple Fiber Handbook*. 3d ed. N. Y., Rayon Pub. Corp., 1939.



- Seabury, William M. *The Public and the Motion Picture Industry*. N. Y., Macmillan, 1926.
- Seligman, Edwin R. A. *The Economics of Installment Selling*. N. Y., Harper, 1927, 2 v.
- Shannon, Fred A. *Economic History of the People of the United States*. N. Y., Macmillan, 1934.
- Shepard, Harold H. *The Chemistry and Toxicology of Insecticides*. Minneapolis, Burgess, 1939.
- Shipley, Maynard. *The War on Modern Science*. N. Y., Knopf, 1927.
- Shreve, R. Norris. *Dyes Classified by Intermediates*. N. Y., Chem. Catalog, 1922.
- *The Chemical Process Industries*. N. Y., McGraw-Hill, 1945.
- Siegfried, André. *America Comes of Age*. Tr. from French by H. H. and Doris Heming. N. Y., Harcourt, Brace, 1927.
- Silberling, Norman J. *The Dynamics of Business*. N. Y., McGraw-Hill, 1943.
- Simonds, Herbert R. *Industrial Plastics*. 3d ed. rev. & enl. N. Y., Pitman, 1945.
- , and Carleton Ellis. *Handbook of Plastics*. N. Y., Van Nostrand, 1943.
- , and others. *The New Plastics*. N. Y., Van Nostrand, 1945.
- Slichter, Sumner H. *Modern Economic Society*. N. Y., Holt, 1931.
- Slosson, Edwin E. *Creative Chemistry*. N. Y., Century, 1920.
- Smith, James G. *Economic Planning and the Tariff*. Princeton, N. J., Princeton U. Press, 1934.
- Smith, J. Russell. *Industrial and Commercial Geography*. New ed. N. Y., Holt, 1930.
- Snell, Foster D., and Cornelia T. Snell. *Chemicals of Commerce*. N. Y., Van Nostrand, 1939.
- Snyder, Carl. *Capitalism the Creator*. N. Y., Macmillan, 1940.
- Solis-Cohen, Solomon, and Thomas S. Githens. *Pharmacotherapeutics, Materia Medica and Drug Action*. N. Y., Appleton, 1928.
- Soule, George H. *The Useful Art of Economics*. N. Y., Macmillan, 1929.
- Spiecker, Karl. *Germany—from Defeat to Defeat*. London, MacDonald, 1945.
- Spurr, Josiah E., and Felix E. Wormser, ed. *The Marketing of Metals and Minerals*. N. Y., McGraw-Hill, 1925.
- Staley, Eugene. *Raw Materials in Peace and War*. N. Y., Council For. Relations, 1937.
- Stieglitz, Julius, ed. *Chemistry in Medicine*. N. Y., Chem. Foundation, 1928.
- Stocking, George W. *The Oil Industry and the Competitive System*. N. Y., Houghton Mifflin, 1925.
- *The Potash Industry*. N. Y., Smith, 1931.
- Stotz, Louis, and Alexander Jamison. *History of the Gas Industry*. N. Y., Stettiner, 1938.
- Stoughton, Bradley, and Allison Butts. *Engineering Metallurgy*. 2d ed. N. Y., McGraw-Hill, 1930.
- Stout, George D. *Edward Mallinckrodt: A Memoir*. St. Louis, privately printed, 1933.
- Sullivan, Mark. *Our Times: 1900-1925*. N. Y., Scribner's, 1928-35, 6 v.
- Survey of American Chemistry*. N. Y., Chem. Catalog, 1925-35, 10 v.
- Sutermeister, Edwin. *Chemistry of Pulp and Paper Making*. 3d ed. N. Y., Wiley, 1941.
- Tarbell, Ida M. *The History of the Standard Oil Company*. N. Y., Macmillan, 1933, 2 v. in 1.

- Taussig, Frank W. *The Tariff History of the United States*. 8th ed. N. Y., Putnam's, 1931.
- Teeple, John E. *The Industrial Development of Searles Lake Brines*. N. Y., Chem. Catalog, 1929.
- Thomas, Edward. *The Law of Chemical Patents*. 2d ed. N. Y., Van Nostrand, 1938.
- Tilden, William A. *Chemical Discovery and Invention in the Twentieth Century*. Rev. by S. Glasstone. N. Y., Dutton, 1936.
- Tippetts, Charles S., and Shaw Livermore. *Business Organization and Control*. N. Y., Van Nostrand, 1932.
- Toothaker, Charles R. *Commercial Raw Materials*. Rev. ed. Boston, Ginn, 1927.
- Toulmin, H. A., Jr. *Millions in Mergers*. N. Y., Forbes, 1929.
- Tousley, R. D. *The Economics of Industrial Alcohol*. Pullman, Wash., State Coll. Wash., 1945.
- Tripp, Guy E. *Super Power as an Aid to Progress*. N. Y., Putnam's, 1924.
- [Trivanovitch, Vaso, and others.] *Rationalization of German Industry*. N. Y., Nat. Ind. Conference Bd., 1931.
- Turrentine, John W. *Potash*. N. Y., Wiley, 1926.
- *Potash in North America*. N. Y., Reinhold, 1943.
- Tyler, Chaplin. *Chemical Engineering Economics*. 2d ed. N. Y., McGraw-Hill, 1938.
- Van Name, Willard G. *Vanishing Forest Reserves*. Boston, Badger, 1929.
- Van Slyke, Lucius L. *Fertilizers and Crop Production*. N. Y., Judd, 1932.
- Van Winkle, Matthew. *Aviation Gasoline Manufacture*. N. Y., McGraw-Hill, 1944.
- Viner, Jacob. *Dumping*. Chicago, U. Chicago Press, 1923.
- Voskuil, Walter H. *The Economics of Water Power Development*. Chicago, Shaw, 1928.
- Waeser, Bruno. *The Atmospheric Nitrogen Industry*. Tr. by Ernest Fyelman. London, Churchill, 1926, 2 v.
- Waggaman, William H., and Henry W. Easterwood. *Phosphoric Acid, Phosphates and Phosphatic Fertilizers*. N. Y., Chem. Catalog, 1927.
- Walker, Joseph F. *Formaldehyde*. N. Y., Reinhold, 1944.
- Wallace, Benjamin B., and Lynn R. Edminster. *International Control of Raw Materials*. Wash., D. C., Brookings Inst., 1930.
- Wallis-Taylor, Alexander J. *Industrial Refrigeration, Cold Storage and Ice-Making*. 7th ed. rev. & enl. by R. J. Cracknell. London, Lockwood, 1929.
- Warburg, Paul M. *The Federal Reserve System*. N. Y., Macmillan, 1930, 2 v.
- Warner, Charles A. *Texas Oil and Gas Since 1543*. Houston, Tex., Gulf Pub. Co., 1939.
- Warshow, Herman T., ed. *Representative Industries of the United States*. N. Y., Holt, 1928.
- Weber, Gustavus A. *The Bureau of Chemistry and Soils*. Baltimore, Johns Hopkins Press, 1928.
- *The Bureau of Standards*. Baltimore, Johns Hopkins Press, 1925.
- *The Food, Drug and Insecticide Administration*. Baltimore, Johns Hopkins Press, 1928.
- Weber, G. M., and Carl L. Alsberg. *American Vegetable-Shortening Industry*. Stanford, Calif., Stanford U. Food Res. Inst., 1934.

- Weeks, Mary E. *The Discovery of the Elements*. 4th ed. Easton, Pa., Mack, 1939.
- Weith, Archie J., and A. V. H. Mory. *Twenty-Five Years of Chemical Engineering Process*. N. Y., Van Nostrand, 1933.
- Wells, Louis R. *Industrial History of the United States*. N. Y., Macmillan, 1922.
- Whitbeck, Ray H., and V. C. Finch. *Economic Geography*. 3d ed. N. Y., McGraw-Hill, 1935.
- Whitmore, Frank C. *Organic Chemistry*. N. Y., Van Nostrand, 1937.
- Wiest, Edward. *Agricultural Organization in the United States*. Lexington, U. Kentucky, 1923.
- Wile, Frederic W., ed. *A Century of Industrial Progress*. N. Y., Doubleday, 1928.
- Wilson, Charles M. *Trees & Test Tubes: The Story of Rubber*. N. Y., Holt, 1943.
- Wilson, John A. *The Chemistry of Leather Manufacture*. 2d ed. N. Y., Chem. Catalog, 1928-29, 2 v.
- Winkler, John K. *The Du Pont Dynasty*. N. Y., Reynal & Hitchcock, 1935.
- Wise, Louis E., ed. *Wood Chemistry*. N. Y., Reinhold, 1944.
- Wolf, Howard, and Ralph Wolf. *Rubber*. N. Y., Covici-Friede, 1936.
- World Conditions as to Mineral Raw Materials for the Fertilizer Industry*. Phila., Nat. Fertil. Assoc., 1926.
- Wormser, René A. *Collection of International War Damage Claims*. N. Y., Alexander, 1944.
- Yoder, Dale. *Labor Economics and Labor Problems*. N. Y., McGraw-Hill, 1933.
- Young, J. F. *Materials and Processes*. N. Y., Wiley, 1944.
- Zanetti, J. Enrique. *The Significance of Nitrogen*. N. Y., Chem. Foundation, 1932.
- Zimmer, Fritz. *Nitrocellulose Ester Lacquers*. Tr. from German by H. K. Cameron. N. Y., Van Nostrand, 1934.
- Zon, Raphael, and William N. Sparhawk. *Forest Resources of the World*. N. Y., McGraw-Hill, 1923, 2 v.



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WILLIAMS HAYNES





## COMPANY AND PERSONAL NAME INDEX

Portraits indicated by asterisk \*; references by italicized number.

Abbott, C., 545  
 Abbott, W. C., 259  
 Abbott Laboratories, 11, 245, 248-9,  
 251, 255, 259, 539  
 Abel, J. J., 250, 288  
 \*Abrams, A., 418, 423\*  
 Acheson, E. G., 435  
 Acheson Graphite Co., 41, 119<sub>n</sub>  
 Acids Manufacturing Corp., 536  
 Ackerson, G. G., 549  
 Acme Manufacturing Co., 511, 518  
 Acme Products Co., 356  
 Acme Rayon Corp., 379, 388<sub>n</sub>, 547  
 Adair Bros. & McCarthy, 327<sub>n</sub>  
 Adams, C. M., 164<sub>n</sub>  
 Adams, F. B., 164<sub>n</sub>  
 Adams, J. B., 325  
 Adams, R., 245<sub>n</sub>, 252, 255, 288, 433<sub>n</sub>  
 Adamson, G. P., 432  
 Adirondack Mineral Co., 420<sub>n</sub>  
 Administratickantor Diligentia, 324<sub>n</sub>  
 Aetna Explosives Co., 39, 202<sub>n</sub>  
 Aetna Life Insurance Co., 213<sub>n</sub>  
 Agassiz, R. I., 341<sub>n</sub>  
 Agfa, 51-52, 52<sub>n</sub>  
 Agfa-Ansco Corp., 236  
 Agress, M., 325  
 Agricultural Potassium-Phosphate Co.,  
 325  
 Ahlquist, H., 126  
 Ahmeck Mining Co., 340  
 Air Reduction Co., 163-4, 342  
 Akt.-Ges. f. Anilin-Fabrikation, *see*  
 Agfa  
 Aktieselskabet Meraker Smelteverk, 41  
 Aktieselskabet Saudefaldene, 41  
 Alabama Chemical Co., 518  
 Alabama Power Co., 105, 319, 336  
 Alachua Tung Oil Co., 366  
 Albany Chemical Co., 135<sub>n</sub>  
 Albany Grease Co., 231<sub>n</sub>  
 Albek, A., 302  
 Albin, T. C., 179, 184, 186  
 Albright, A. R., 397-8  
 Albright, H. M., 331  
 Aldridge, W., 433<sub>n</sub>

Alexander, J., 41<sub>n</sub>, 434, 436  
 Alexander, O. L., 380<sub>n</sub>  
 Algon Color & Chemical Corp., 536  
 Alleman, G., 240  
 Allen, 98  
 \*Allen, E. M., 26<sub>n</sub>, 86<sub>n</sub>, 89<sub>n</sub>, 95, 119\*,  
 125, 191<sub>n</sub>, 434, 438, 549  
 Allen, F. W., 380<sub>n</sub>  
 Allen, J., 129<sub>n</sub>  
 Allen, W. H., 108  
 Allen, W. P., 189<sub>n</sub>, 373<sub>n</sub>  
 Alliance Fertilizer Company, 328  
 Allied Chemical & Dye Corp., 24, 33,  
 40, 40<sub>n</sub>, 68<sub>n</sub>, 86, 87<sub>n</sub>, 90, 177, 210,  
 210<sub>n</sub>, 220, 259<sub>n</sub>, 317<sub>n</sub>, 318, 541  
 Allied Tar & Chemical Corp., 222, 536  
 Allouez Mining Co., 340  
 Almy, C., 413  
 Alox Chemical Co., 223  
 Alox Corp., 223<sub>n</sub>  
 Alrose Chemical Co., 231<sub>n</sub>  
 Alston-Lucas Paint Co., 373  
 Althouse Chemical Co., 237  
 Alton Banking & Trust Co., 137  
 Alton Barium Product<sup>c</sup> Co., 137-8, 524  
 Altoona Laboratories, Pennsylvania  
 R.R., 137<sub>n</sub>  
 Aluminum Company of America, 122<sub>n</sub>,  
 132, 140-41, 144  
 Aluminum Ore Co., 523  
 Alyco Manufacturing Co., 255, 536  
 Amalgamated Phosphate Co., 45<sub>n</sub>  
 Amann, A., 357<sub>n</sub>  
 Ambruster, H. W., 49<sub>n</sub>, 376<sub>n</sub>, 382<sub>n</sub>  
 American Agar Co., 424  
 American Agricultural Chemical Co.,  
 33, 101, 322<sub>n</sub>, 327<sub>n</sub>, 328-9, 345, 511,  
 518  
 American Airlines, 23<sub>n</sub>  
 American Alcohol Co., 162, 423<sub>n</sub>  
 American Aniline Products, Inc., 253,  
 373  
 American Anode, Inc., 413  
 American Barium Co., 136  
 American Bauxite Co., 132, 132<sub>n</sub>  
 American Beet Sugar Co., 423<sub>n</sub>

- American Bemberg Corp., 380, 384-5, 388<sub>n</sub>, 547  
 American Borvisk Co., 378-9  
 American Bromine Co., 264  
 American Catalin Corp., 349, 536  
 American Cellulose & Chemical Co., 382<sub>n</sub>  
 American Cellulose & Chemical Manufacturing Co., Ltd., 185, 350<sub>n</sub>  
 American Chatillon Corp., 381, 384, 388<sub>n</sub>, 547  
 American Column & Lumber Co., 9  
 American Commercial Alcohol Corp., 165, 257  
 American Commercial Alcohol Company of California, 165  
 American Copperas Co., 72  
 American Cyanamid & Chemical Corp., 44<sub>n</sub>  
 American Cyanamid Co., 43-46, 56, 69<sub>n</sub>, 90<sub>n</sub>, 92-93, 94<sub>n</sub>, 102, 135, 201, 219<sub>n</sub>, 257, 313, 318, 321, 328, 333, 342, 359, 434, 511, 513, 518  
 American Disinfecting Co., 344<sub>n</sub>  
 American Distilling Co., 165  
 American Dyewood Co., 421<sub>n</sub>  
 American Enka Corp., 380, 385<sub>n</sub>, 388, 547  
 American Fluoride Corp., 342<sub>n</sub>  
 American Glanzstoff Corp., 379, 384, 388, 388<sub>n</sub>, 547  
 American Home Products Corp., 290, 303  
 American I.G. Chemical Corp., 234, 236, 396  
 American International Corp., 124<sub>n</sub>  
 American Magnesium Corp., 140-41  
 American Maize-Products Co., 423-4  
 American Mercury Co., 268  
 American Metal Co., Ltd., 189<sub>n</sub>, 299<sub>n</sub>, 341<sub>n</sub>, 371<sub>n</sub>  
 American Molasses Co., 165  
 American Nitrates Co., 320  
 American Nitrogen Products Co., 14, 86, 92, 130, 320-21  
 American Nuplax Corp., 354  
 American Potash & Chemical Corp., 28, 144, 324  
 American Potash Co., 325-6  
 American Powder Co., 46<sub>n</sub>, 359  
 American Railway Express Co., 26  
 American Raw Silk Co., 385  
 American Rolling Mill Co., 518  
 American Sheet & Tin Plate Co., 413<sub>n</sub>, 511  
 American Smelting & Refining Co., 271, 334, 336-7, 340, 341<sub>n</sub>, 371-2, 399  
 American Sodium Co., 129  
 American Solvents & Chemical Corp., 164-5, 192, 204, 360, 536  
 American Steel & Wire Co., 511  
 American Sugar Co., 162  
 American Sulphur Co., 80  
 American Tar Products Co., 210, 211<sub>n</sub>, 222  
 American Trona Co., 272, 323-4, 324<sub>n</sub>  
 American Tung Oil Corp., 365-6  
 American Turpentine & Tar Co., 356, 414  
 American Vat Color Co., 231<sub>n</sub>  
 American Vulcanized Fibre Co., 413<sub>n</sub>  
 American Wood Reduction Co., 178  
 American Woolen Co., 417  
 American Zinc & Chemical Co., 511  
 American Zinc Co., 71  
 American Zinc, Lead & Smelting Co., 371<sub>n</sub>, 511  
 Ames, J. T., 157<sub>n</sub>, 167  
 Amido Products Co., 536  
 Ammonia Casale Société Anonyme de Basle, 88  
 Ammonia Corp., 87  
 Amolin Co., 303  
 Amoskeag Manufacturing Co., 379  
 Amsterdamsche Chininefabriek, 284, 285<sub>n</sub>  
 Anaconda Copper Mining Co., 98<sub>n</sub>, 101-2, 334, 337-40, 341<sub>n</sub>, 370, 511, 518  
 Anderson, H. W., 84, 240  
 Anderson, J., 382  
 Anderson, J. H., 322<sub>n</sub>, 341<sub>n</sub>  
 Anderson, U. S. G., 233  
 Anderson Chemical Co., 42<sub>n</sub>, 192, 353  
 Anderson Co., V. D., 546  
 Anderson Fertilizer Works, 322<sub>n</sub>, 511, 518  
 Andes Copper Mining Co., 341<sub>n</sub>  
 Andrew, J. P., 261  
 Andrews, L. C., 154-5, 159, 282  
 Anglo-Chilean Consolidated Nitrate Corp., 315-6, 316<sub>n</sub>  
 Anglo-Chilean Nitrate Co., 315<sub>n</sub>  
 Anglo-Chilean Nitrate & Railways Co., Ltd., 315  
 Anglo-Persian Oil Co., 394  
 Ansbacher, A. B., 373  
 Ansbacher, D. A., 344  
 Ansbacher & Co., A. B., 345, 373  
 Ansbacher Insecticide Co., 373  
 Ansbacher-Siegle Corp., 536  
 Antrim Iron Co., 518  
 Apache Powder Co., 513  
 Apex Chemical Co., 536

- Apple, W. D., 344*n*  
 Arco Co., 265*n*  
 Arden Salt Co., 264  
 Arkansas Bauxite Products Co., 137  
 Arkansas Fertilizer Co., 518  
 Arlington Co., 33, 37*n*  
 Arlington Mills, 417, 539  
 Armand Co., 278  
 Armour, B. R., 253, 373  
 Armour, J. O., 393  
 Armour & Co., 68*n*, 98, 239*n*, 365*n*, 410, 422, 546  
 Armour Fertilizer Works, 45, 71, 318, 322*n*, 327*n*, 511, 518, 523, 541  
 Armstrong, E. R., 262  
 Arnold, Hoffman & Co., 115-6, 229, 232  
 Arny, H. V., 252, 255, 440  
 Aromatic Products, Inc., 302*n*  
 Aronson, D., 126  
 Arsenic Products & Refining Co., 335  
 Arthur, H. A., 164*n*, 381*n*  
 Asbury, W. C., 396  
 Ashfield, Lord, 57*n*  
 Ashland By-Product Coke Co., 210  
 Associated Dyeing & Printing Corp., 417  
 Associated Securities of Canada, Ltd., 506  
 Atherton, H. F., 549  
 Athletic Mining & Smelting Co., 371*n*  
 Atkins & Co., E., 162  
 Atlantic Chemical Co., 511  
 Atlantic Coast Line Railroad Co., 421  
 Atlantic Creosoting Co., 536  
 Atlantic Dyestuff Co., 104*n*, 229  
 Atlantic Refining Co., 394  
 Atlas Luminite Cement Co., 135  
 Atlas Portland Cement Co., 523  
 Atlas Powder Co., 39, 189*n*, 190, 353, 359*n*, 360*n*, 385, 417, 513  
 Atmospheric Nitrogen Corp., 86, 86*n*, 88, 90, 93  
 Atom Chemical Corp., 536  
 Atteaux, F. E., 237  
 Atwood, L., 392*n*  
 Ault & Wiborg Co., 236, 415  
 Auramine Corporation of America, 536  
 Aussiger Verein, *see* Verein  
 Austin, J. B., 225  
 Austin, S. F., 77  
 Averill, E. M., 103  
 Avery Chemical Co., 236*n*, 511  
 Aycock, L. M., 225  
 Aylsworth, J. W., 216, 349*n*, 535  
 Ayres, E. E., Jr., 204  
 Babo, L. V., 350*n*  
 Bach, R., 304  
 \*Bacharach, L. S., 158*n*, 164, 166\*  
 Bachmeier, J. H., 232  
 Bachmeier & Co., 232  
 Back, E. A., 344*n*  
 Backus, A. A., 433  
 Bacon, C. V., 436  
 Bacon, F., 229  
 Bacon, R. F., 76*n*, 83  
 Bacorn, W. C., 338  
 Badger, W. L., 225, 549  
 Badger & Sons Co., E. B., 163*n*  
 Badische Anilin und Soda Fabrik, 33, 51-53, 68-69, 169-72, 175-6, 234, 239*n*, 404, 419*n*, 511, 539  
 Badische Co., 539  
 Backeland, L. H., 11, 159, 215, 348, 354, 398*n*, 549  
 Baeyer, A. von, 133, 207  
 Bailar, J. C., Jr., 346, 375  
 Bailey, L. H., 109  
 Bain, H. F., 314*n*  
 \*Baird, C. C., 246\*, 254*n*  
 Baird & M. Guire, 254, 344*n*  
 Bakelite Corp., 214*n*, 215-6, 222, 348-9, 349*n*, 401, 536  
 Baker, F. C., 324*n*  
 Baker, H. P., 355  
 Baker, J. T., 203  
 Baker & Bro., H. J., 183, 323*n*  
 Baker Chemical Co., J. T., 202  
 Baketel, H. S., 253  
 Baldwin, A. E., 142*n*  
 Baldwin, R. T., 26, 26*n*, 119*n*, 125, 204, 439, 549  
 Baldwin-Lewis-Pace Co., 356*n*  
 Balfour, A., 256  
 Ballard, Inc., James F., 216  
 Balsam, A. R., 381*n*  
 \*Balsam, D. M., 374\*, 381*n*  
 Banca Agricola Italiana, 379*n*  
 Bancroft, W. D., 260, 390, 435*n*, 549  
 Bancroft & Sons Co., Joseph, 125*n*  
 Bandoengsche Kininefabriek, 284, 285*n*  
 Banigan Rubber Co., Jos., 97*n*  
 Bankers Trust Co., 232*n*, 383*n*  
 Banks, H. W., 3rd, 341  
 Banthien, H., 316  
 Barada & Co., A. S., 117*n*  
 Barber, E. J., 23, 504  
 Barbour Chemical Works, 511  
 Barclay, G. S., 182*n*  
 Bardcke, J., 344*n*  
 Bare Paper Co., D. M., 522  
 Barium Mining Corp., 524

- Barium Products, Ltd., 124, 136, 139, 524  
 Barium Reduction Corp., 137-9, 195, 524  
 Barker Chemical Co., 511, 518  
 Barnard, L. L., 16  
 Barnett, E. A., 550  
 Barney, A. L., 298<sub>n</sub>  
 Barney & Co., Chas. D., 289<sub>n</sub>  
 Barnsdall Corp., 193, 394, 405  
 Barnum, W. N., 285  
 \*Barr, J. A., 97-98, 109, 118\*  
 Barrett, W. F., 183, 196, 549  
 Barrett Co., 87, 210-12, 214, 216, 220, 313, 317<sub>n</sub>, 330  
 Barrett & Co., M. L., 304  
 Barrows, S. H., 264  
 Barry, E. J., 436<sub>n</sub>  
 Barstow, E. O., 260  
 Bartlett, E. R., 95  
 Bartlett, H. J., 268  
 \*Bartlett, J. E., 278\*, 289  
 Barton, D. C., 84  
 Bartow, E., 549  
 Baruch, B., 75  
 Baryta Manufacturing Co., 188<sub>n</sub>  
 Bass, L. W., 20<sub>n</sub>, 389  
 Bassett, H. P., 300  
 Bassett, W. H., 549  
 Batchelor, J. J., 213<sub>n</sub>  
 Bates, H. R., 314<sub>n</sub>, 434  
 Bates Chemical Co., 536  
 Bauer, F. M., 259  
 Bauer Bros., 545  
 Baugh Chemical Co., 341<sub>n</sub>, 511, 518  
 Baugh & Sons Co., 322<sub>n</sub>, 327<sub>n</sub>, 518  
 Baxter, W. J., 427  
 Bay Chemical Co., 129  
 Bayer, C. J., 122<sub>n</sub>  
 Bayer Co., 247-8, 254-5, 290, 343, 411  
 Bayer & Co., *see* Farbenfabriken v. F. Bayer & Co.  
 Bayer-Semesan Co., 343  
 Bayway Industrial Chemical Co., 360  
 Beachville White Lime Co., 44  
 Beal, C. L., 413<sub>n</sub>  
 \*Beal, G. D., 247\*, 252, 428  
 Beal, G. P., 84  
 \*Beal, J. H., 154, 279, 283  
 Beam, V. H., 544  
 Beans, H. T., 436  
 Bear, F. E., 313, 329, 331  
 Beardsley, A. P., 95  
 Beaver Chemical Corp., 45, 231, 234  
 Beaver Refining Co., 210<sub>n</sub>  
 Bebie, J., 217  
 Becker, J., 209, 213  
 Beckers Aniline & Chemical Works, W., 40<sub>n</sub>, 231, 237<sub>n</sub>  
 Becket, F. M., 142<sub>n</sub>, 330  
 Bedaux, C., 191<sub>n</sub>  
 Bedford, C. W., 414  
 Bedford, F. T., 164<sub>n</sub>  
 Beilstein, C., 304  
 Belamose Corp., 379, 388<sub>n</sub>, 547  
 Belknap, C., 42  
 Bell, F. P., 182<sub>n</sub>  
 Bell, T. M., 321  
 Bell, W. B., 44  
 Bell Telephone Laboratories, 193<sub>n</sub>  
 Belle Alkali Co., 192, 203, 522, 536  
 Belle Chemical Co., 300  
 Belle Chemical Products Co., 536  
 Bellefont Associates, 231<sub>n</sub>  
 Bemberg A.-G., J. P., 53, 380  
 Bemis Bros. Bag Co., 418<sub>n</sub>  
 Bendelari, A. E., 371<sub>n</sub>  
 Bené & Sons, John, 138  
 Benjamin, E. B., 129<sub>n</sub>  
 \*Benjamin, E. V., 129<sub>n</sub>, 134\*  
 Benner, S. R., 116  
 Benner Chemical Co., 116  
 Benney, I., 306  
 Benrath, C., 380<sub>n</sub>  
 Benson, H. K., 169<sub>n</sub>  
 Bent, L. N., 357<sub>n</sub>  
 Bentley, R., 72  
 Benton, L., 392<sub>n</sub>  
 Benzol Products Co., 255, 536  
 Berg Industrial Alcohol Co., David, 162, 163<sub>n</sub>, 165  
 Berghausen Chemical Co., E., 536  
 Bergius, F., 53, 395, 535  
 Berkshire Chemical Co., 328  
 Berry, C. W., 324  
 \*Berry, E. R., 420, 422\*, 427  
 Berry, F. D., 203  
 Berry Chemical Co., Thomas, 182  
 Bertha Mineral Co., 138  
 Bertrand Freres, Inc., 303<sub>n</sub>  
 Bertsch, J. A., 69  
 Berzelius, J. J., 358<sub>n</sub>  
 Best Foods, Inc., 398  
 Bethlehem Steel Corp., 70, 212, 262, 379, 518  
 Bevan, E. T., 383<sub>n</sub>  
 Bevans, J. W., 281<sub>n</sub>  
 Bevier, G. M., 76<sub>n</sub>  
 Bianchi, C. A., 300  
 Bichowsky, F. von, 368  
 \*Biebinger, O. L., 258, 262\*  
 Bigelow, H. W., 280, 282<sub>n</sub>  
 Bigelow, W. D., 549  
 Billings, E., 416<sub>n</sub>

- Billiter, J., 120  
 Biltmore Industries, 380*n*  
 Binney & Smith Co., 416, 416*n*  
 Birch, S., 340  
 Birch Lumber Co., S. M., 300  
 Birdseye, C., 425, 428  
 Birge, W. W., 379  
 Birn & Wachenheim, Inc., 353  
 Biroli, M., 381*n*  
 Bischoff & Co., C., 236  
 Bisodol Co., 290  
 Bitler, W. P., 156  
 Black, C. K., 368*n*  
 Black, H. L., 322  
 Black, I. A., 225  
 Blackshear Manufacturing Co., 511, 518  
 Blair, D. H., 152-4  
 Blair, F. A., 11, 154  
 Blair, P. A., 539  
 Blair & Co., 193  
 Blöck, J. W., 102  
 Blockson Chemical Co., 102, 518  
 Blue, R., 281*n*  
 Bluethgen, F., 380, 384  
 Blum, A., 352*n*  
 Blum, H. L., 352*n*  
 Blumenfeld, J., 368  
 Blumenthal, F. H., 29  
 \*Bobst, E. H., 278\*, 278*n*, 285  
 Bocqueraz, L., 359  
 Bocqueraz, R., 359  
 Boehringer & Söhne, C. F., 290  
 Rogert, M. T., 252, 286*n*  
 Bogue, R. H., 435*n*  
 Bolton, E. K., 240, 400, 539  
 Bond, B. C., 241  
 Bond, R. H., 153*n*, 154  
 Bondt, 199*n*  
 Bondy, W., 323  
 Bonnet, F., 388  
 Bonnie, R. P., 233  
 \*Bonnie, S., 231\*, 233  
 Booge, J. E., 369  
 Boord, C. E., 399  
 Booth, C. F., 225  
 Boots Pure Drug Co., Ltd., 251  
 Borgstrom, P., 391  
 Born, S., 392*n*  
 Borvisk Kunstseiden, 378  
 Bosch, C., 52, 236, 236*n*, 404  
 Bosquil, F. L., 109  
 Bostwick, H. R., 80  
 Boswell, M. C., 81, 84  
 Boughton, E. W., 375  
 Bovinine Co., 290  
 Bower, R. F., 320  
 Bower, W. H., 549  
 Bowker, H., 322*n*, 328-9  
 Bowker, R. C., 428  
 Bowker Chemical Co., 101, 345, 518  
 Bowman, F. C., 30, 102, 102*n*, 109  
 \*Boyd, T. A., 260, 260*n*, 272, 391\*, 396*n*, 398-400, 407  
 Boyer, D. L., 104  
 Boyer, E. A., 145  
 Boyer, J. W., 23, 292, 437, 437*n*, 504, 550  
 Boyer, M. W., 396  
 \*Boylston, A. C., 259, 259*n*, 262\*  
 Braden Copper Co., 341*n*  
 Bradshaw, H., 213  
 Brady, J. W. S., 213*n*  
 Braeburn Steel Co., 254*n*  
 Braham, J. M., 95, 314*n*  
 Brallier, P. S., 126, 202, 205  
 \*Brand, C. J., 13, 311\*, 322, 327, 329, 329-31, 433*n*  
 Brandel, I. W., 137  
 Brandenberger, J. E., 351  
 \*Braun, F. W., 327\*, 342  
 Braun & Co., F. W., 342*n*  
 Braun Corp., 342  
 Braun-Knecht-Heimann Co., 342  
 Bregeat Corporation of America, 140*n*  
 Breithut, F. E., 26*n*, 549  
 Brent, C. E., 281*n*  
 Brevolite Lacquer Co., 39  
 Brewer & Co., 11*n*  
 Brewster, B. H., Jr., 322*n*  
 Brewster, T. J., 183-4  
 \*Breyer, F. G., 358\*, 369, 375  
 Briden, L. L., 237  
 Brininstool, F. M., 373*n*  
 Bristol-Myers Co., 290  
 British Celanese, Ltd., 237, 383  
 British Columbia Electric Railway Co., 92  
 British Copper Manufacturers, Ltd., 57  
 British Dyes, Ltd., 57  
 British Dyestuffs Corp., Ltd., 56, 57*n*  
 British Metals Corp., 340  
 British Molasses Co., 161  
 British Saccharin Manufacturing Co., 42  
 British Titan Products Co., 368*n*  
 \*Britton, E. C., 198\*, 216, 225, 332, 535  
 Britton, J. W., 536  
 Broadbridge, W., 98  
 Brock, F. P., 349*n*  
 Brogdon, J. S., 342*n*  
 Brokmeyer, E. C., 282*n*  
 Brooke Iron Co., E. & G., 518

- Brooklyn Color Works, 373  
 Brooks, B. T., 192, 192*n*, 205, 390, 391*n*, 392*n*, 406, 439  
 Brooks, G. S., 370*n*  
 Brother, G. H., 361  
 Brotherton & Co., 42, 212  
 Brown, A., 222*n*  
 Brown, A. L., 357  
 Brown, B. K., 187, 201*n*, 204  
 \*Brown, C. O., 55\*, 86*n*, 87, 89*n*, 90, 92*n*, 93, 95  
 Brown, D., 38*n*, 402  
 Brown, E. W., 440  
 Brown, F. C., 324*n*  
 Brown, G., 222*n*  
 Brown, H. B., 232*n*  
 Brown, H. F., 165  
 Brown, H. S., 539  
 Brown, J. J., 336  
 Brown, K., 222*n*, 349*n*  
 Brown, R. R., 161*n*  
 \*Brown, S., 214\*, 214*n*, 222, 225, 401  
 Brown, W. E., 269, 273  
 Brown Bros. & Co., 289*n*  
 Brown Co., 203, 386, 522, 536  
 Brown Guano Co., D., 518  
 Brown-Leithold Co., 359  
 Brown & Sons, Alex., 289*n*  
 \*Browne, C. A., 386, 438  
 Browne, S. C., 74-75  
 Browne, W. A., 83  
 Brownell, F. H., 340  
 Brownlee, H. J., 350, 361, 544  
 Brownstead, J. P., 145  
 Bruce, W. C., 153  
 Brumberger, E. S., 384*n*  
 Brunkow, O. R., 204  
 Brunner, Sir J., 57*n*  
 Brunner-Mond & Co., Ltd., 56, 57*n*, 262  
 Brush, H. R., 273  
 Brush, M. C., 124*n*  
 Buck, J. M., 291*n*  
 Buckeye Soda Co., 118  
 Buckhannon Chemical Co., 185  
 Budgen, N. F., 375  
 Bueb, J., 313-4, 317  
 Buerck, C. A., 417  
 Buffalo Electro-Chemical Co., 417  
 Buffington, J., 69*n*  
 Buffum, W. W., 539  
 Bunker Hill & Sullivan Mining & Concentrating Co., 370, 372  
 Bunsen, R. W. von, 141  
 Burbach Kaliwerke A.-G., 55*n*  
 \*Burdick, A. S., 11, 259, 262\*, 549-50.  
 Burgess, L., 205  
 Burgess Laboratories, C. F., 187*n*  
 Burnham Chemical Co., 326*n*  
 Burns, H. S., 75  
 Burns, I. H., 181  
 Burns, W., 296  
 Burr, G. H., 380*n*  
 Burr & Co., Geo. H., 380*n*  
 Burrell, G., 390  
 \*Burroughs, C. F., 310\*, 322*n*, 329  
 Burroughs Wellcome & Co., 290  
 Burrows, J. T., 322*n*  
 Burt, M. C., 182*n*, 185  
 Burton, W. A., 190  
 \*Burton, W. M., 390\*, 391, 393  
 Burton Powder Co., 46*n*  
 Burwell, A. W., 226  
 Bush, B. T., 297, 301-2, 549  
 Bush, Inc., Burton T., 298, 301, 305, 536  
 Bush Aromatics, Inc., 301  
 Butler, P. H., 365  
 Butte Copper & Zinc Co., 370*n*  
 Butters' (Cyanidation Plant), 335  
 Butterworth, C. M., 23, 504  
 Butterworth-Judson Co., 211, 239*n*  
 Button Corporation of America, 354  
 Byers, H. G., 436, 549  
 Byrne, P. J., Jr., 396  
 Cable Chemical Works, 536  
 Cabot, G. L., 417*n*  
 Cabot, Inc., Godfrey L., 415-6  
 Cabot, Inc., Samuel, 254*n*  
 Cadillac, 324  
 Cadillac Chemical Co., 173  
 Cadillac-Soo Lumber Co., 174*n*, 180, 185  
 Caesar, D., 226  
 Cahours, A., 350*n*  
 Cain, J. W., 77  
 Calbeck, J. H., 371, 375  
 Calco Chemical Co., 28, 44-46, 94, 221, 230*n*, 231-2, 240, 255, 257, 373*n*, 435*n*, 511, 513, 538-9  
 Calcott, W. S., 400  
 Calder, D. S., 175*n*, 186  
 Caldwell, 541  
 California Chemical Corp., 264, 265*n*, 536  
 California Cyanide Co., 89, 342  
 California Rock Salt Co., 265  
 California Spray Chemical Co., 341, 345  
 Calingaert, G., 400  
 \*Callahan, M. J., 180\*, 187, 358, 433  
 Callan, W., 95  
 Callis, C. C., 402

- Calman, H. L., 365  
 Calumet & Arizona Mining Co., 340, 341*n*, 511  
 Calumet Chemical Co., 103, 518, 523  
 Calumet Fertilizer Corp., 518  
 Calumet & Hecla Consolidated Copper Co., 340  
 Calumet & Hecla Mining Co., 340, 341*n*  
 Calvert, G. C., 171  
 \*Camp, G. L., 260, 263\*  
 Camp Fertilizer Co., 328  
 Campbell, C. C., 362  
 Campbell, G. R., 341*n*  
 Campbell, W. B., 406  
 Canada Carbide Co., 146  
 Canadian Celanese, Ltd., 383  
 Canadian Electro Products Co., Ltd., 131, 182-3, 183*n*, 194  
 Canadian Industries, Ltd., 37*n*, 58, 506*n*  
 Canadian Salt Co., 266  
 Canadian Titanium Pigments Co., 368*n*  
 Cananea Consolidated Copper Co., 341*n*  
 Canel, E. B., 372*n*  
 Capes-Viscose, Inc., 352  
 Capital City Acid Phosphate Co., 518  
 Capital Fertilizer Co., 519  
 Caracristi, V. Z., 214  
 Caraleigh Phosphate & Fertilizer Works, 327*n*, 365*n*, 511, 519  
 Carbic Color & Chemical Co., 236  
 Carbide and Carbon Chemicals Corp., 40, 61*n*, 123, 160, 184*n*, 194-9, 200*n*, 205, 343, 392, 405-6, 422, 433  
 Carbinol Products Co., 189*n*  
 Carbon Dioxide & Chemical Co., 426  
 Carborundum Co., 523  
 Carey, G., 164*n*  
 Carey, W. F., 99*n*  
 Carey Co., Philip, 271  
 Carlisle, P. J., 205  
 Carnegie, W. R., 373*n*  
 Carnegie Steel Co., 213  
 Carnrick Co., G. W., 289  
 Caro, N., 43*n*  
 Carolina Chemical Co., 327*n*  
 Carothers, J. N., 104-5, 106*n*, 110  
 Carpenter, J. D., 260*n*, 272, 396*n*  
 Carpenter, W. S., Jr., 38*n*  
 Carr, C. McD., 380*n*  
 Carr, R. L., 416*n*, 427  
 Carrell, H. G., 26*n*, 116, 137  
 Carson Carbon Co., 415  
 Carson Naval Stores Co., 356*n*  
 Carter, A., 82  
 Carter, J. B., 269, 273  
 Carter, J. P., 183, 191  
 \*Carter, S. L., 310\*, 322*n*, 328-9  
 Carus Chemical Co., 233*n*  
 Casale, L., 37, 87-88, 319  
 Case, F. O., 370*n*  
 Case, L. B., 16  
 Casebourne & Co., 57  
 Casein Company of America, 354  
 Casein Manufacturing Co., 44*n*  
 Cassel, E. T., 273  
 Cassell Cyanide Co., 57  
 Cassella & Co., Leopold, 51-52, 52*n*, 233  
 Castlebury, F. E., 321*n*  
 Castner, H. Y., 114  
 Castner-Kellner Alkali Co., Ltd., 56  
 Catalin Corp., 349*n*  
 Catalytic Process Corp., 45  
 Catawba Fertilizer Co., 519  
 Catchings, W., 258  
 Cayuga Lake Cement Co., 254*n*  
 Celanese Corporation of America, 185*n*, 350, 382*n*, 383, 547  
 Celaron Co., 537  
 Celluloid Co., 537  
 Celluloid Corp., 383, 537  
 Celluloid Manufacturing Co., 350-51  
 Celluloid Zapon Co., 39, 353  
 Celotex Corp., 419  
 Centennial Mining Co., 340  
 Central Carbon Co., 415*n*  
 Central Chemical Co., 327*n*, 328, 511, 523  
 Central Commercial Company, 143  
 Central Dyestuff & Chemical Co., 233  
 Central Railroad Company of Georgia, 421  
 Centaur Co., 11  
 Century Carbon Co., 416  
 Chadeloid Chemical Co., 414  
 Chambers, J. S., 344*n*  
 Champion Fibre Co., 522  
 Champion Porcelain Co., 136  
 Chance & Hunt, 79*n*  
 Chandler, C. F., 107, 435  
 Chaney, N. K., 549  
 \*Charch, W. H., 342\*, 352, 352*n*  
 Charcoal Iron Co., 185  
 Chardonnet, Count de, 381, 384*n*  
 Charleston Chemical Co., 87  
 Chase, F. L., 397  
 Chase, K. N., 343*n*  
 Chase, M. F., 68*n*  
 Chase, P. H., 262  
 Chatfield, H. S., 153*n*, 155*n*  
 Chattanooga Gas & Coke Co., 178  
 Chaubert, P., 79  
 Cheeseman, F. P., 373  
 Cheeseman, Elliott Co., 373

- \*Cheetham, C. L. E., 55\*, 87  
 Chemical Company of America, 229, 233  
 Chemical Construction Co., 70-71, 437, 510-11  
 Chemical Construction Corp., 46, 90<sub>n</sub>  
 Chemical & Dye Corp., 233, 537  
 Chemical Engineering Corp., 46  
 Chemical Manufacturing Co., 229  
 Chemical & Pigment Co., 28, 369, 524  
 Chemical Solvents, Inc., 183  
 Chemical Treatment Co., 141  
 Chemico, Inc., 511  
 Chemische Fabrik auf Aktien vorm. E. Schering, 300<sub>n</sub>  
 Chemische Fabrik Griesheim-Elektron, 52<sub>n</sub>  
 Chemische Fabrik von Heyden, 254  
 Chemische Fabrik Niederheim, 138  
 Chemische Fabriken Dr. Kurt Albert G.m.b.H., 357<sub>n</sub>  
 Chemische Fabriken Weiler-ter-Meer, 52<sub>n</sub>  
 Chemo Co., 344<sub>n</sub>  
 \*Chen, K. K., 279\*, 283-4, 540  
 Cheney, F. D., 539  
 Cheney Bros., 539  
 Chesley, A. J., 403<sub>n</sub>  
 Chew, J. A., 23, 108, 124<sub>n</sub>, 504  
 Chicago By-Product Coke Co., 209, 541  
 Chicago Copper & Chemical Co., 137-9, 524  
 Chickamauga Fertilizer Works, 519  
 Childs, H. H., 211<sub>n</sub>  
 Childs Pulp Colors, Inc., 537  
 Chile Copper Co., 339, 341<sub>n</sub>  
 Chile Exploration Co., 140<sub>n</sub>, 141<sub>n</sub>  
 Chilhowee Co., 422  
 Chilton, T. H., 95  
 Chinosol Co., 539  
 Chipman, R. N., 334<sub>n</sub>, 346  
 Chipman Chemical Engineering Co., 335, 337, 345  
 Chiris Co., Antoine, 297<sub>n</sub>, 301-2  
 Chisos Mining Co., 123<sub>n</sub>, 268  
 Chittick, M. B., 205  
 Choate, J. H., Jr., 539  
 Christensen, P. C., 354  
 Christiansen, W. G., 539  
 Chromium Corporation of America, 141-2  
 Chromium Products Corp., 141  
 Churchill, J. B., 425<sub>n</sub>, 428  
 Churchill Drug Co., 117<sub>n</sub>  
 Ciba Co., 236, 239<sub>n</sub>  
 Cincinnati Chemical Works, 236  
 Cities Service Oil Co., 193, 392<sub>n</sub>  
 Claflin, A. A., 237, 241  
 Clancy, J. C., 86<sub>n</sub>  
 Clark, C. T., 183  
 Clark, E. M., 393, 396, 396<sub>n</sub>, 401-2, 403<sub>n</sub>  
 Clark, E. P., 431<sub>n</sub>  
 Clark, L. H., 192, 204  
 Clark, R. A., 203  
 Clark, T. A., 165  
 Clark, W. H., 223<sub>n</sub>  
 Clark Chemical Co., 118, 522  
 Clarke, B. R., 379  
 Clarke, L. W., 326, 331  
 Clarke, R. D., 191<sub>n</sub>  
 \*Clarke, R. E., 134\*, 140  
 Claude, G., 36-37, 87-88, 90  
 Claudel, P., 323  
 Clausen, A. P., 344<sub>n</sub>  
 Clawson, F. F., 182<sub>n</sub>, 185  
 Clawson Chemical Co., 185  
 Clay, C. B., 328  
 Clayton, G. C., 57<sub>n</sub>  
 Clayton Aniline Co., 57  
 Clements, F. O., 397  
 Cleveland-Cliffs Iron Co., 511, 518  
 Cliffs Chemical Co., 182  
 Clinchfield Products Corp., 137  
 Clinchfield Sand & Feldspar Co., 524  
 Clinton Corn Syrup Refining Co., 423  
 Clope, I. S., 538  
 Coad, R. W., 129<sub>n</sub>  
 Coal Tar Dyes, Inc., 537-8  
 Coale, J. S., 322<sub>n</sub>  
 Cochran, R., 72  
 Cochran Chemical Co., 42<sub>n</sub>  
 Colasta Co., 537  
 Cole, R. R., 106, 110  
 Cole, W. H., 288  
 Colgate, A., 7  
 Colgate, G., 11  
 Colgate, R., 303  
 Colgate, S. M., 303  
 Colgate & Co., 7<sub>n</sub>, 11, 27, 155<sub>n</sub>, 278, 295, 297, 303, 304<sub>n</sub>  
 Colgate-Palmolive-Peet Co., 303  
 Colloidal Products Co., 70<sub>n</sub>  
 Colonial Iron Co., 518  
 Colorado Insecticides, Inc., 335  
 Coltexo Corp., 415  
 Columbia Chemical Co., 115, 521  
 Columbia Engineering & Management Corp., 93<sub>n</sub>  
 Columbia Naval Stores Co., 356<sub>n</sub>  
 Columbia Steel Corp., 518  
 Columbian Carbon Co., 415, 416<sub>n</sub>  
 Columbus Fertilizer Co., 519



- Colvin, W. H., Jr., 265  
 Combustion Engineering Corp., 94, 212  
 Commercial Acid Co., 33, 42  
 Commercial Chemical Co., 336<sub>n</sub>  
 Commercial Molasses Co., 189<sub>n</sub>  
 Commercial Pigments Corp., 368  
 Commercial Solvents Corp., 88, 93, 160, 171<sub>n</sub>, 175-7, 187-91, 201, 368, 526<sub>n</sub>  
 Commonwealth Chemical Corp., 123, 259, 306  
 Compañía S.A. de Explosivos, 506  
 Compañía Mexicana de Explosivos, S.A., 39  
 Compressed Carbonic Co., 163  
 Comptoir des Textiles Artificiels, 351  
 Compton, J. N., 196, 205  
 \*Concannon, C. C., 6\*, 9<sub>n</sub>, 11, 12<sub>n</sub>, 13, 16, 61<sub>n</sub>, 326, 365<sub>n</sub>, 375, 433<sub>n</sub>  
 Condensite Company of America, 222, 222<sub>n</sub>, 349<sub>n</sub>, 358  
 Condon, J. F., 302<sub>n</sub>  
 Congaree Fertilizer Co., 519  
 Coniagas Reduction Co., 366  
 Conley, N. B., 233  
 Connelly, T. F., 182<sub>n</sub>  
 Connolly, M. J., 359<sub>n</sub>  
 Conover, C., 41, 208, 219-20, 225  
 Consolidated Carbon Corp., 415<sub>n</sub>  
 Consolidated Chemical Industries, Inc., 29, 72  
 Consolidated Chemical Products Co., 137  
 Consolidated Color & Chemical Co., 233  
 Consolidated Copper Mines Co., 341<sub>n</sub>  
 Consolidated Gold Fields of South Africa, Ltd., 324  
 Consolidated Lead & Zinc Co., 372  
 Consolidated Water Power & Paper Co., 419<sub>n</sub>  
 Consumers Chemical Co., 116  
 Contentnea Guano Co., 519  
 Contex Color Co., 373  
 Continental Carbon Co., 416  
 Continental-Diamond Fibre Co., 537  
 Continental Oil Co., 394  
 Continental Turpentine & Rosin Corp., 357<sub>n</sub>  
 Cooke, L., 292, 306, 370  
 Cooks Falls Dye Works, 229  
 Coolahan, R. A., 204  
 Coolidge, C., 426  
 Coolidge, Calvin, 8, 9, 13-15, 90, 175, 216, 218, 281, 320-21, 321<sub>n</sub>  
 Cooper, G. S., 116<sub>n</sub>  
 Cooper, K., 313  
 Cooper, R. W., 375  
 Cooper & Co., Chas., 353, 360<sub>n</sub>  
 Copeland, H. N., 349  
 Copper Exporters, Inc., 340  
 Copper Pyrites Corp., 82  
 Corbin, A. L., 436  
 Corbitt, H. B., 256  
 Corkins Chemical Co., 344<sub>n</sub>  
 Corliss Carbon Co., 41  
 Corn Products Refining Co., 189<sub>n</sub>, 191, 299<sub>n</sub>, 350<sub>n</sub>, 423  
 Cornelison, R. W., 550  
 Cornell Wood Products Co., 418<sub>n</sub>  
 Cornstalk Products Co., 387  
 Corona Cord Tire Co., 411  
 Coronet Phosphate Co., 107<sub>n</sub>  
 Corrigan, McKinney Steel Co., 518  
 Corse, W. M., 433  
 Corwine, W. R., 10<sub>n</sub>  
 Cory, R. H., 289<sub>n</sub>  
 Coslett, 108<sub>n</sub>  
 Cosmic Color Co., 373  
 Coster, D., 291  
 \*Cotton, R. T., 326\*, 333, 343, 344<sub>n</sub>, 347  
 Cotton Oil Refining Corp., 192<sub>n</sub>  
 Cotton States Fertilizer Co., 327<sub>n</sub>, 328, 511, 519  
 Cottrell, F. G., 91, 107, 313<sub>n</sub>  
 Coule, T. J., 372<sub>n</sub>  
 Couper, W., 75  
 Coursen, W. L., 382  
 Courtauld, S., 376-8, 388  
 Courtaulds, Ltd., 376, 383  
 Couzens, J., 159  
 Covell, B. S., 362  
 Cowie, R. E. M., 26  
 Cox, E. H., 256  
 Coyle, T., 205  
 Coyne, J. K., 25<sub>n</sub>  
 C. P. Chemical Solvents, Inc., 163<sub>n</sub>, 192  
 Crady, W., 329  
 Cragin Products Co., 164  
 Cramer, T. M., 145<sub>n</sub>  
 Cramton, L. C., 153, 159  
 Crane, E. J., 549  
 Crane, E. N., 37<sub>n</sub>  
 Crane, F. D., 549  
 Crane, J. E., 37, 86<sub>n</sub>, 404, 434  
 \*Crass, M. F., 7\*, 27, 29  
 Crawford, F. M., 361  
 Crawford, W. H., 357<sub>n</sub>  
 Creighton, H. J. M., 39  
 Crescent Industrial Alcohol Co., 164  
 Crist, J. L., 231<sub>n</sub>, 232  
 Croen, H. F., 302<sub>n</sub>  
 Crosby, L. O., 366  
 Cross, C. F., 383<sub>n</sub>

Cross, R., 393  
 Cross, W. M., 393  
 Crossett Chemical Co., 180  
 Crossett Lumber Co., 179  
 Crossley, M. L., 240, 435*n*, 539, 549  
 Crouch Mining Co., Wm. J., 523  
 Crounse, W. L., 27*n*, 153*n*, 280, 282*n*  
 Crowley, A. J., 80  
 Crown Chemical Corp., 44, 45*n*, 221, 231, 537  
 Crown Tar Works, 537  
 Crystal Carbon Co., 415  
 Crystal Chemical Co., 163, 426*n*  
 Crystal Color & Chemical Works, 537  
 Cuban Distilling Co., 162  
 Culpepper, C. W., 324  
 Cumberland Carbon Co., 415, 415*n*  
 Cummer & Diggins Co., 182  
 Cumming, H. S., 403  
 Cumming, W. J., 172*n*  
 Cundall, K. N., 84  
 Cuno, C. W., 375  
 Cupra, Inc., 385  
 \*Curme, G. O., Jr., 182\*, 194, 197*n*, 199*n*, 205  
 Currier, R. J., 237  
 Curtin-Howe Corp., 124  
 \*Curtis H. A., 88*n*, 91*n*, 92*n*, 93*n*, 311\*, 313, 314*n*, 320-21, 327*n*, 329, 331, 433*n*, 539, 549  
 Curtis & Harvey, Ltd., 137*n*  
 Custer City Chemical Co., 185  
  
 Dabney, W. C., 361  
 Daigger & Co., A., 416*n*  
 Dalton, N. N., 303  
 Damon, S., 76*n*  
 Dannenbaum, W., 37, 88*n*  
 Danner, H. E., 240, 539  
 Darco Sales Corp., 211*n*  
 Darling & Co., 327*n*, 519  
 Darlington, B., 47  
 Daugherty, H. M., 8  
 Daugherty, W. T., 12*n*, 13*n*, 62, 63, 169  
 \*Dauler, H. N., 210, 214\*  
 Dauler Oil Co., 210*n*  
 \*David, S. R., 215\*, 237*n*  
 David Chemical Co., Albert, 537  
 David & Co., S. R., 237, 239*n*  
 Davidson, J. G., 196, 197*n*, 200*n*, 433  
 Davies, H. R., 236  
 Davies, M. L., 130  
 Davies, W. C., 96*n*  
 Davis, C. W., 93*n*, 221  
 Davis E., 16  
 Davis, G., 380*n*  
 Davis, G. H. B., 396, 405

Davis, H. P., 5  
 Davis, H. S., 76*n*, 83, 381*n*  
 Davis, J. B., 356*n*  
 Davis & Co., J. B., 356*n*  
 Davis & Geck, 46*n*  
 Davison Chemical Co., 70-71, 82-83, 98-99, 322*n*, 327, 327*n*, 328, 394, 511, 513, 519  
 Davison-Gulfport Fertilizer Co., 511  
 Davison-Pick Fertilizers, Inc., 519  
 Davison Sulphur Co., 82*n*  
 Davison Sulphur & Phosphate Co., 99  
 Dayton Metal Products Co., 399  
 Dayton Power & Light Co., 260  
 \*De Florez, L., 394, 406\*, 406  
 \*De Greef, R. H., 279\*, 285, 285*n*, 286, 417*n*  
 \*De Guigne, C., 29, 38\*  
 De Haën, C. J. E., 68, 83  
 De Jahn, F. W., 86  
 De Jonigan, 106  
 De Long, C. R., 10*n*, 11, 173, 272  
 DeLore, C. P., 372  
 DeLore Co., C. P., 372, 524  
 D'Olier, F., 380*n*  
 De Ong, E. R., 81, 84  
 DeVaney, F. D., 109  
 Dean, A. L., 287, 292  
 Dean, E. W., 397*n*, 405  
 Death Valley Sulphur Co., 80  
 Deimann, 199*n*  
 Del Rio, 41*n*  
 Delahanty, T. W., 12*n*, 13, 61*n*  
 Delaware Rayon Corp., 379, 388, 388*n*, 547  
 Delaware River Steel Co., 518  
 Deller, A. W., 426  
 Delore Smelting & Refining Co., 134*n*  
 Delta Chemical & Iron Co., 518  
 Denbigh, Lord, 82, 328  
 Denby, E., 8  
 Deneen, C. S., 321  
 Denham, J. S., 352*n*  
 Denhey Corp., 253  
 Denney & Denney, 296  
 \*Dent, H. M., 342\*, 349  
 Denver Chemical Manufacturing Co., 253*n*  
 \*Derby, H. L., 26*n*, 38\*, 44-45, 549  
 Derby, I. H., 211  
 Derick, C. G., 238  
 Dermatological Research Laboratories, 259  
 Deschiens, M., 361  
 Deshell Laboratories, 290  
 Despaisses, L. H., 384*n*  
 Detroit Chemical Works, 513

- Deutsche Gasolin, 53  
 Deutsche Solvay Works, 55<sub>n</sub>  
 Devoe & Raynolds Co., 345  
 Dewar, J., 393<sub>n</sub>  
 Dewey, B., 413  
 Dewey & Almy Chemical Co., 413  
 Dexter, J. R., 213<sub>n</sub>  
 Dial, N. B., 320  
 Diamond, H. W., 226  
 Diamond Alkali Co., 35<sub>n</sub>, 111, 115-6, 116<sub>n</sub>, 118-9, 123, 144, 212, 521-2  
 Diamond Fertilizer Co., 519  
 Diamond Match Co., 130  
 Diamond State Fibre Co., 537  
 Diarsenol Laboratories, 249  
 Dickey, C. D., 289<sub>n</sub>  
 Dickinson & Co., J. Q., 265  
 Dicks, David Co., 13<sub>n</sub>, 231<sub>n</sub>  
 Dickson, J. B., 412  
 Dieckmann, J. H., Jr., 186  
 Diehlmann, G. M., 304  
 Dieterle, G. F., 158<sub>n</sub>  
 Dietrich, H. E., 361  
 Diggins, D. F., 173  
 Dighton Color Works, 114<sub>n</sub>  
 Dill, C., 183  
 Dill & Collins Co., 522  
 Dinkins, P. M., 23, 504  
 Dispersions Process, Inc., 414  
 Distillers Securities Corp., 162  
 Dixie Bauxite Co., 523  
 Dixie Guano Co., 511, 519  
 Dixie Pine Products Corp., 356, 357<sub>n</sub>  
 Dobeckmun Co., 352<sub>n</sub>  
 Dockwiler & Kingsbury Co., 519  
 Dodd, R., 361  
 Dodge, F., 304  
 Dodge, F. D., 297  
 Dodge, F. E., 549  
 Dodge & Olcott, 298, 304  
 Doe Run Lead Co., 372  
 Doebereiner, J. W., 349<sub>n</sub>, 350<sub>n</sub>  
 Doerner, H. A., 146  
 Doherty, H. L., 385  
 Doherty, T. J., 173  
 Doherty & Co., Henry L., 211  
 Doherty Research Corp., 193  
 Doherty Silk Co., Henry, 385  
 \*Dohme, A. R. L., 251<sub>n</sub>, 256, 278\*, 289  
 Dolbear, C. E., 324  
 Dold, B. W., 539  
 Dolge Co., C. B., 344<sub>n</sub>  
 Dolt, M. L., 435<sub>n</sub>  
 Domado Mining Co., 372  
 Domeratzky, L., 63, 346, 389  
 Dominguez Chemical Co., 513  
 Dominion Textiles, Ltd., 239<sub>n</sub>  
 Donnell, J. C., 390  
 Donovan, W. J., 9<sub>n</sub>, 12, 285  
 Doran, J. M., 159, 163, 199  
 Dorland, R. E., 23, 504, 550  
 Dorner, B., 387  
 Dorr, J. V. N., 107, 549  
 Dorr Co., 135<sub>n</sub>  
 Dotterweich, F. H., 95  
 Doty, E., 137  
 Doty, H. S., 410, 412<sub>n</sub>  
 Douglas, C. V., 116<sub>n</sub>  
 Douglas, W., 340  
 Dovon Chemical Corp., 410-11, 537  
 Dow, H. H., 20<sub>n</sub>, 140-41, 222, 225, 260-61, 263, 534, 549  
 Dow, W. H., 113<sub>n</sub>, 120<sub>n</sub>, 121<sub>n</sub>, 140<sub>n</sub>, 260<sub>n</sub>, 267<sub>n</sub>  
 Dow Chemical Co., 23, 28, 35<sub>n</sub>, 36, 113, 120<sub>n</sub>, 121, 121<sub>n</sub>, 139-41, 146, 200, 203, 214<sub>n</sub>, 215-6, 221, 236, 254-5, 260-65, 265<sub>n</sub>, 267, 270, 273, 332, 345, 410<sub>n</sub>, 412<sub>n</sub>, 522, 534-6  
 Downs, C. F., 220, 225, 436, 439, 549  
 Downs, J. C., 119  
 Dox, A. W., 252  
 Drachenberg, A. T., 77  
 Drackett, H. R., 117<sub>n</sub>  
 Drackett, P. W., Jr., 117  
 Drackett Chemical Co., 117<sub>n</sub>  
 Drackett Products Co., 117<sub>n</sub>  
 Drackett & Sons Co., P. W., 117<sub>n</sub>  
 Dresdner Bank, 18<sub>n</sub>  
 Drexel & Co., 289<sub>n</sub>  
 Dreyer, P. R., 303  
 Dreyer, P. R., Inc., 303  
 Dreyfus, C., 350-51, 382-3, 383<sub>n</sub>  
 Dreyfus, H., 350-51, 382  
 Dreyfus, T. F., 357<sub>n</sub>  
 Drouillard Co., J. C., 372  
 Dru, L. A. G., 324<sub>n</sub>  
 Drug, Inc., 236<sub>n</sub>, 290  
 Drummond, J. C., 433  
 Drury, A. C., 304  
 DryIce Corp., 426  
 DuBois, G. F., 217<sub>n</sub>  
 DuMez, A. G., 292  
 Du Pont, H. F., 38<sub>n</sub>  
 Du Pont, I., 38<sub>n</sub>, 39, 262, 313, 403<sub>n</sub>, 426  
 \*Du Pont, L., 11, 38<sub>n</sub>, 39, 205, 352<sub>n</sub>, 549  
 Du Pont, P. S., 38, 38<sub>n</sub>, 39  
 Du Pont Ammonia Corp., 88, 177, 537  
 Du Pont Building Corp., 506  
 Du Pont Cellophane Co., 37, 351-2, 506

- Du Pont de Nemours & Co., E. I., 11,  
 23, 27<sub>n</sub>, 33, 36-39, 45, 57, 71, 87-88,  
 88<sub>n</sub>, 90, 92-93, 93<sub>n</sub>, 108, 121<sub>n</sub>, 123<sub>n</sub>,  
 135, 160, 165, 166<sub>n</sub>, 171<sub>n</sub>, 172, 175-7,  
 187<sub>n</sub>, 189<sub>n</sub>, 190, 192, 194, 202-4,  
 211<sub>n</sub>, 213, 220-21, 228, 234, 236,  
 261-2, 300, 301<sub>n</sub>, 313, 318, 343, 351-  
 3, 358-9, 360<sub>n</sub>, 369, 373, 391, 395,  
 399-400, 403, 403<sub>n</sub>, 404, 410-12, 414,  
 417, 420, 425-6, 433, 433<sub>n</sub>, 434, 437,  
 506, 511, 513, 522, 538-9, 541  
 Du Pont Engineering Co., 506  
 Du Pont Fibersilk Co., 378  
 Du Pont National Ammonia Co., 37,  
 88, 506  
 Du Pont Nitrate Co., 506  
 Du Pont Pathe Film Manufacturing  
 Corp., 506  
 Du Pont Rayon Co., 37, 378, 381-3,  
 385<sub>n</sub>, 386, 388, 388<sub>n</sub>, 506, 547  
 Du Pont Viscoloid Co., 353, 506  
 \*Dubbs, C. P., 393, 406\*  
 Dubbs, J. A., 393  
 Duchemin, E. P., 184<sub>n</sub>  
 Ducktown Chemical & Iron Co., 81-82,  
 511, 513  
 Ducktown Pyrites Corp., 82  
 Ducktown Sulphur, Copper & Iron Co.,  
 Ltd., 81  
 Dudley, C. B., 137<sub>n</sub>  
 Dudois & Roswell, 259  
 Duecker, W. W., 83-84  
 Duisberg, W., 396<sub>n</sub>  
 Duke, B. N., 328  
 Duke, J. B., 44, 434  
 Dulles, J. F., 329  
 Dumas, J., 425<sub>n</sub>  
 Dunbar, J. B., 231<sub>n</sub>  
 Dunbar Molasses Co., 162-3, 165  
 Duncali, R. K., 210<sub>n</sub>  
 \*Dunker, C. H., 215\*, 231  
 Dunker & Perkins Co., 231  
 Dunlap, E., 107  
 Dunlop Rubber Co., 413  
 Dunning, G. M., 437<sub>n</sub>  
 \*Dunning, H. A. B., 246\*, 250  
 Dunstan, A. E., 146, 394  
 Duplate Corp., 420<sub>n</sub>  
 Dupont, J., 433  
 Durand & Huguenin S.A., 14, 236  
 Durant, W. C., 38<sub>n</sub>  
 Duratex Corp., 417  
 Durez Co., 349  
 Duriron Co., 437  
 Durite Plastics, Inc., 349, 349<sub>n</sub>, 544  
 Durrett, J. J., 281  
 Duval Texas Sulphur Co., 77  
 Dwight, R. E., 258  
 Dwight & Lloyd Sintering Co., 135<sub>n</sub>  
 Dye Products & Chemical Co., 45, 436  
 Dyes, W. A., 29  
 Dyes & Chemicals, Inc., 537  
 Dyes & Chemicals of New Jersey, Inc.,  
 537  
 Dyestuffs Corporation of America, 236  
 Dynamit A.-G. vorm. A. Nobel & Co.,  
 38, 506  
 Dyson, G. M., 272  
 Eagle Lye Works, 118  
 Eagle-Picher Lead Co., 371, 371<sub>n</sub>, 372,  
 524  
 Eagle-Picher Zinc Co., 369, 511, 513  
 Eames, M. H., 396<sub>n</sub>  
 Eastern Alcohol Corp., 161, 163, 165,  
 203, 426, 506  
 Eastern Color Co., 537  
 Eastern Cotton Oil Co., 327<sub>n</sub>, 328  
 Eastern Electrolytic Zinc, Inc., 370  
 Eastern Manufacturing Co., 522  
 Eastern Potash Corp., 323  
 Eastman Kodak Co., 29, 178, 185,  
 189<sub>n</sub>, 190, 353, 412-3, 433<sub>n</sub>, 513  
 Ebaugh, W. C., 399  
 Eberlin, L. W., 413  
 Echols, A. B., 165  
 Eckelmann, L. E., 110  
 Ecker, F. E., 251  
 Eckert, R. R., 340  
 Eddy, E. W., 84  
 Eddeleanu, L., 394, 405, 406  
 Edgar, D. R., 181<sub>n</sub>  
 \*Edgar, G., 261, 391\*, 403<sub>n</sub>  
 Edgar, H. T., 181<sub>n</sub>  
 Edgar Bros. Co., 181<sub>n</sub>  
 \*Edge, J. B. D., 37, 39\*, 313  
 Edison, T., 419  
 Edmonds, R. W., 83, 84  
 Edsall, D. L., 403<sub>n</sub>  
 Edser, E., 98  
 Edwards, C. B., 211  
 Edwards, E. I., 153, 155  
 Edwards, E. T., 145  
 Egloff, G., 201<sub>n</sub>, 392<sub>n</sub>, 406  
 Egyptian Lacquer Manufacturing Co.,  
 189<sub>n</sub>, 190  
 Ehrlich, P., 248-9  
 Ehrman, E. H., 344<sub>n</sub>  
 Ekroth, C. V., 436  
 Elder, A. L., 83  
 Electric Bond & Share Co., 77<sub>n</sub>, 88,  
 108  
 Electro Bleaching Gas Co., 28  
 Electro Metallurgical Co., 141-2

Electrolytic Zinc Process Co., 370n  
 Elektron Metals Corp., 141  
 Eliason, J. B., 343n, 539  
 Elizabethton Trust Co., 380  
 Elko Chemical Co., 42, 224, 232n, 414, 537  
 Ellenberger, E. P., 346  
 Elley, H. W., 306  
 Elliott's Metal Co., Ltd., 57  
 Ellis, C., 193, 201, 204, 361, 392n, 393, 414  
 Ellis, G., 322n  
 Ellis, M., 538  
 Ellis, R. R., 27n  
 Ellwood, L. E., 329  
 Elm, A. C., 375  
 Elworthy, H. S., 425n  
 Elworthy, R. T., 199n, 407  
 Emerson, I. E., 264, 434  
 Emerson Drug Co., 264  
 Emery, W. O., 539  
 Emery Candle Co., 203  
 Emlaw, H. S., 324n  
 Emley, W. E., 428  
 Emmet, W. L., 268  
 Empire Biochemical Co., 537  
 Empire Gas & Fuel Co., 193  
 Empire Size & Chemical Co., 420n  
 Empire State Chemical Co., 327n, 519  
 Empire State Fertilizer Co., 511  
 Enka-Maekubee, 380n  
 \*Eno, G. M., 7\*, 23, 26n, 504  
 Equitable Powder Manufacturing Corp., 506  
 Equitable Trust Co., 163  
 Erinoid Co., 354  
 Erinoid Company of America, 354  
 Ernst, F. A., 86n, 88n  
 Ernst, R. P., 153n  
 Essex Aniline Works, 45n, 229  
 Etablissements Kuhlmann, 58, 90  
 Etablissements Poulenc Frères, 248-50, 302  
 Ethyl Corp., 402  
 Ethyl Gasoline Corp., 261n, 262, 265, 399n, 402-3, 403n  
 Etiwan Fertilizer Co., 327n, 511, 519  
 Euramerican Cellulose Products Corp., 387  
 Evans, G. B., 285n  
 Evans, R. M., 87  
 Evans-Wallower Zinc Co., 370  
 Everett Distilling Co., 164  
 Everett & Sons, Allen, 57  
 Ewart, C. B., 124n  
 Excelsior Salt Works, 265  
 Exolon Co., 523

Fabrique de Soie Artificielle de Tubize, 381  
 Fairbrother, T. H., 205  
 Fairchild, D., 364n  
 Fairlie, A. M., 68n, 342n  
 Fairmont Chemical Co., 511  
 Fall, A. B., 8  
 Fallon, P. P., 302n  
 Falls Rubber Co., 411  
 Faraday, M., 207  
 Farbenfabriken v. F. Bayer & Co., 51-52, 52n, 233-5, 237n, 239, 246-7, 249  
 Farbwerke Hoechst, 51-52, 52n, 233, 250  
 Farleigh, H. S., 26, 26n, 114n  
 Farmer, A. J., 550  
 Farmers' Federated Fertilizer Corp., 321  
 Farmers' Fertilizer Co., 327n, 511, 519  
 Farmers' Guano Co., 519  
 Farwell, O. A., 283n  
 Faust, J. B., 272, 330  
 Fawkes, C. E., 359  
 Federal Alcohol Co., 162  
 Federal Chemical Co., 327n, 329, 423n, 511, 519  
 Federal Color Laboratories, Inc., 373, 537  
 Federal Dyestuff Co., 104n  
 Federal Lead Co., 371  
 Federal Phosphorus Co., 103-5, 107, 110, 222-3, 336, 423, 518, 537  
 Federal Power Corp., 321n  
 Federal Products Co., 158n, 164, 303n  
 Federal Sugar Co., 162  
 Feeley, E. J., 232  
 Feeley, Inc., E. J., 232  
 \*Felton, J., 295\*, 297, 302  
 Felton, J. S., 373  
 Felton, S., 302  
 Felton Chemical Co., 192, 297-8, 302, 537  
 Felton, Sibley & Co., 373  
 Ferguson, C. S., 358n, 362  
 Fernbach, A., 190  
 Fiberloid Corp., 182n  
 Fieldner, A. C., 213n, 403, 407  
 Fields Point Manufacturing Co., 123  
 Fiersz, H. E., 241  
 Fierz-David, 539  
 Filatex Corp., 353n  
 Finch Chemical Co., L. S., 537  
 Fine Colors Co., 373  
 \*Fink, C. G., 135\*, 141-2, 254  
 Fink, F. W., 254  
 Fireman, P., 375  
 Firemen's Insurance Co., 232n

- Fischer, E., 247  
 Fish, E. A., 289<sub>n</sub>  
 Fish, Richardson & Neave, 187<sub>n</sub>  
 Fisher, F. J., 142<sub>n</sub>  
 Fisher, G. A., 422  
 Fisher, H. G. M., 261-2  
 Fisher, H. L., 413  
 Fisher, M. D., 165  
 Fisher & Keller, 237<sub>n</sub>  
 Flaherty, E. M., 359  
 Flannery, M. M., 344  
 Fleischmann Co., 423-4  
 Fleming, A. H., 434  
 Fleming, R., 393  
 Fleming, S. T., 374  
 Fleming & Co., Robert, 383<sub>n</sub>  
 Fletcher Chemical Co., 537  
 Florasynth Laboratories, 192  
 Flynt Silica & Spar Co., 524  
 Fogarty, F. L., 356<sub>n</sub>  
 Fogg, D. E., 72<sub>n</sub>  
 Fogg, I., 47  
 Fonda, L., 288  
 Fonrobert, E., 357<sub>n</sub>, 362  
 Forbes, C. R., 8  
 Forbes, H. A., 323<sub>n</sub>  
 Forbes Varnish Co., 361  
 Force, C. W., 26<sub>n</sub>, 211  
 Ford, E. B., 236  
 Ford, H., 132, 319, 398  
 Ford Motor Co., 179-80, 214, 236, 359, 420, 537  
 Forest Products Chemical Co., 178, 179<sub>n</sub>, 180, 182, 184  
 Forrest Bros., 385  
 Fort Smith Spelter Co., 371<sub>n</sub>  
 \*Fortner, L. B., 215\*, 237  
 Fortner Co., L. B., 237  
 Foster-Wheeler Corp., 394  
 Fougera & Co., E., 291  
 Fourneau, E., 249<sub>n</sub>  
 Fournier, L. T., 62  
 Fowler, A. H., 426  
 Fownes, G., 349<sub>n</sub>  
 Fox, E. J., 330  
 Fox, H. S., 13<sub>n</sub>, 63  
 Franco-American Chemical Works, 162<sub>n</sub>, 166, 192, 204, 270, 353  
 Frank, A., 43<sub>n</sub>  
 Franklin, E. C., 549  
 Frary, F. C., 122, 131<sub>n</sub>  
 Frasch, E. B., 436  
 Frasch, H., 74-77, 394, 436  
 Frazar & Co., 410<sub>n</sub>  
 Frederick, J. G., 26, 62  
 Frederick Disinfecting Co., 344<sub>n</sub>  
 Freedman, L., 240, 539  
 Freeman, H., 131, 145-6  
 Freeport Sulphur Co., 73-75, 75<sub>n</sub>, 76, 78-79, 83  
 Freeport Texas Co., 84  
 Fremed, H. D., 259  
 Fremont Cotton Oil Co., 328  
 French, P., 229  
 \*French, R. H., 163<sub>n</sub>, 166\*, 192, 205  
 French-American Bank, 359  
 Ferichs, F. W., 549  
 Fresenius, K. R., 285<sub>n</sub>  
 Friedman, J., 538  
 Fries, A. A., 26, 266, 346, 439, 440  
 Fries, G. G., 297  
 Fries, H. H., 297  
 Fries, R. G., 297  
 Fries Bros., 305  
 Fries & Fries, Inc., 192, 297-8, 305  
 \*Fritz, H. E., 407\*, 413  
 Fritzsche Bros., 288<sub>n</sub>, 297<sub>n</sub>, 299  
 Frolich, P. K., 199  
 Frutkow, N., 190<sub>n</sub>  
 Fry, H. E., 343<sub>n</sub>  
 Fryer, L. S., 384<sub>n</sub>  
 Fuchs, von, 143  
 Fuller, H. C., 205  
 \*Fuller, R. S., Jr., 375\*, 388  
 \*Fulton, C. A., 99, 109, 118\*  
 Fulton, K. H., 156  
 Fulweiler, W. H., 224  
 Funk, C., 275<sub>n</sub>, 549  
 Furman Fertilizer Works, 511, 519  
 Furness, J. W., 29  
 Furness, W. H., 385  
 Furness Corp., 385, 547<sub>n</sub>  
 Fusi, S., 381<sub>n</sub>  
 \*Gabriel, C. L., 176<sub>n</sub>, 183\*, 186, 188, 204-5, 361  
 Gainey, P. L., 316  
 Galloway, H. J., 539  
 Galt, H. A., 549  
 Gann, J. A., 146  
 Gardiner, W. S., 210  
 \*Gardner, H. A., 346, 359\*, 365, 365<sub>n</sub>, 374  
 Garfield, H. A., 433  
 Garfield Aniline Works, 45, 234  
 Garis, H. H., 203  
 Garner, J. B., 426  
 Garrett, G., 20  
 Garrigues Co., Chas. F., 317<sub>n</sub>  
 Garrigues, Stewart & Davies, 317<sub>n</sub>  
 Garvan, F. P., 10<sub>n</sub>, 239-40, 288, 430<sub>n</sub>, 434-5, 539  
 Gaskill Chemical Corp., 45  
 Gaus, W., 404

- Gebrüder Giulini G.m.b.H., 108  
Geddes, Sir A., 82  
Geer, W. C., 426, 549  
Geigy Co., 236-7  
Geigy S.A., J. R., 237*n*  
Gellard, W. B., 381*n*  
General Abrasive Co., 523  
General Alcohol Export Corp., 164*n*  
General Aniline Works, 234-6, 238, 537  
General Atlas Carbon Co., 415, 427  
General Atlas Chemical Co., 211, 415  
General Chemical Co., 23-25, 27, 33, 56, 69-70, 72, 82, 83, 86, 94, 101, 102*n*, 135, 192*n*, 259, 260*n*, 299*n*, 318, 333*n*, 338, 341, 345, 432, 510-11, 513, 518, 523  
General Chromium Corp., 142  
General Dyestuff Corp., 37, 233-6, 248, 257, 539  
General Electric Co., 141*n*, 171*n*, 268, 336, 358, 420, 433, 433*n*, 537  
General Foods Corp., 425  
General Industrial Alcohol Corp., 164-5, 257  
General Motors Chemical Co., 260-61, 401-2  
General Motors Corp., 36, 38, 38*n*, 57, 142*n*, 171*n*, 175, 272, 358, 391, 396, 397*n*, 398*n*, 399-400, 402, 506  
General Motors Research Corp., 261*n*, 352*n*  
General Motors Securities Co., 506*n*  
General Plastics, Inc., 349, 537  
General Reduction & Chemical Co., 371  
General Refractories Co., 523  
General Salt Co., 267  
General Synthesis Co., 537  
Genesee Chemical Co., 122  
George, W. F., 116  
George Chemicals, Inc., W. F., 116  
Georgia, W. Z., 172*n*, 181, 185  
Georgia Fertilizer Co., 511, 519  
Georgia-Louisiana Chemical Co., 419  
Georgia-Louisiana Corp., 420*n*  
Georgia Pine Turpentine Co., 414  
Gephart, F. C., 436  
Geraghty, J. T., 250  
Giant Powder Co., 39  
Gibbs, H. D., 41, 201, 208, 219-20, 240, 539  
Gibbs, W. T., 120  
Gibson, J., 357*n*  
Gide, P., 323  
Gide, R., 323, 323*n*  
Gilbert, M. E., 124*n*  
Gilchrist, H. L., 272, 439  
Giles, J. L., 264  
Gillet, C., 352*n*  
Gillican-Chipley Co., 355  
Girard & Co., 291  
Givaudan, L., 301  
Givaudan & Cie, L., 297*n*, 301  
Givaudan-Delawanna, Inc., 297*n*, 299, 301, 302*n*, 537  
Glanzstoff, *see* Vereinigte; also American Glanzstoff  
Gleason, R., 142*n*  
Glenk, R., 306  
\*Gleysteen, G. N., 215\*, 234*n*, 538-9  
Glidden Co., 28*n*, 135*n*, 359, 369  
Globe Bauxite Co., 132*n*  
Gloor, W. E., 361  
Glyco Products Co., 537  
Goddard, A. E., 381*n*  
Goering, T., 184  
Goff, W., 437*n*  
Golden Giant Mining Co., 365*n*  
Golden State Co., Ltd., 140*n*  
Goldman, M. H., 344*n*  
Goldman, Sachs & Co., 258  
Goldschmidt, H., 58  
Goldschmidt, S. A., 431*n*  
Goldsmith Bros., 181*n*  
Gollmar, H. A., 84  
\*Goodell, G. A., 231\*, 233  
Goodman, G. W., 137  
Goodrich Rubber Co., B. F., 412-3, 413*n*  
Goodwin, H. M., 122, 126  
Goodyear Rubber Co., 224*n*, 414  
Gordon, H. D., 549  
\*Gordon, J. B. (Bureau of Raw Materials, Wash., D.C.), 359\*  
Gordon, W. T., 539  
Goshorn, J. H., 368*n*  
Goss, M. J., 201  
Gottlob, K., 411  
Goulden, H. D., 269, 273  
Govers, F. X., 404  
Grace, M. H., 433*n*  
Grace & Co., W. R., 316  
Grace Nitrate Co., 316  
Graesser-Monsanto Chemical Works, Ltd., 42, 69, 212  
Graff, C. J., 320  
Grafius, A. B., 329  
Graham, E. A., 288  
Graham, R. N., 196  
Grant Co., W. T., 381  
Granton Chemical Co., 45*n*  
Grasselli, E. R., 10*n*  
Grasselli, T. S., 36*n*, 344

- Grasselli Chemical Co., 11, 23, 27<sub>n</sub>,  
 36-37, 72, 82, 101, 123, 135<sub>n</sub>, 142,  
 233-4, 235<sub>n</sub>, 247, 344-5, 369, 371<sub>n</sub>,  
 411, 512-3, 518-9, 523-4  
 Grasselli Dyestuff Corp., 221, 233-5,  
 239, 353  
 Grasselli Powder Co., 37  
 Graves, A. D., 373  
 Gray, C. H., 330  
 \*Gray, G. W. (Texas Corp.), 406\*  
 Gray, H., 412<sub>n</sub>  
 Gray, McD., 407  
 Gray, T. T., 394  
 Gray, W. S., 26<sub>n</sub>  
 Gray Chemical Co., 185  
 Gray & Co., Wm. S., 182  
 Great Northern Chemical Co., 158  
 Great Southern Sulphur Co., 129  
 Great Western Electro-Chemical Co.,  
 89, 124, 426<sub>n</sub>, 522  
 Great Western Sugar Co., 524  
 Greaves-Walker, A. F., 428  
 Greeff & Co., R. W., 219<sub>n</sub>, 284-5, 285<sub>n</sub>,  
 416, 417<sub>n</sub>  
 Green, E. H., 258  
 Green, J. L., 299  
 Green, M., 108  
 Green River Carbon Co., 415<sub>n</sub>  
 Greenburg, L., 213<sub>n</sub>  
 Greendale Co., 165  
 Greene, E., 229  
 Greene-Cananea Copper Co., 341<sub>n</sub>  
 Greenhalgh, Z., 237  
 Greif, W., 236<sub>n</sub>  
 Griesheim-Elektron, *see* Chemische  
 Fabrik Griesheim-Elektron  
 Griffith & Boyd Co., 327<sub>n</sub>, 512, 519  
 Grillo, W., 70  
 Grimm, R. H., 165  
 Griswold, B. H., Jr., 289<sub>n</sub>  
 Groggins, P. H., 146, 205, 221, 225  
 Gross, P. A., 265  
 Grosvenor, W. M., 436, 439, 549  
 Groves Fertilizer Works, 519  
 Guaranty Trust Co., 124<sub>n</sub>  
 Gubelmann, I., 228, 306  
 Guernsey, F. W., 370  
 Guffey, J. M., 76<sub>n</sub>  
 Guggenheim Bros., 315-6, 340  
 Guide Printing & Publishing Co., 103<sub>n</sub>  
 Gulf Oil Corp., 133-4, 394  
 Gulf Production Co., 77-78  
 Gulf Refining Co., 132<sub>n</sub>, 135<sub>n</sub>, 210<sub>n</sub>,  
 394, 513, 522-3  
 Gulf States Chemical & Refining Co.,  
 336  
 Gulfport Fertilizer Co., 519  
 Gundelfinger, W. G., 116  
 Guthrie, W. D., 240  
 Guyan Color & Chemical Works, 234,  
 237  
 Guyot, A., 214<sub>n</sub>  
 Haarmann & Reimer Chemische Fab-  
 rik, 302  
 Haas, O., 357  
 Haber, F., 86, 91, 91<sub>n</sub>, 170, 318, 320  
 Hackley-Phelps-Bonnell Co., 182  
 Haebler, T., 302<sub>n</sub>  
 \*Haebler, W. T., 294\*, 302  
 \*Haertel, M. H., 146, 167\*, 167, 172,  
 179<sub>n</sub>, 185, 186  
 Haff, M. M., 105  
 \*Hagar, I. D. (Titanium Pigments  
 Corp.), 358\*  
 Hager, H. E., 235  
 Haile, J. C., 357<sub>n</sub>  
 \*Halbach, E. K., 230\*, 234<sub>n</sub>, 235, 241  
 Hale, H., 266, 267<sub>n</sub>, 272  
 \*Hale, W. J., 198\*, 214<sub>n</sub>, 215-6, 221,  
 225-6, 238, 242, 432, 440, 534-6  
 Hall, C. B., 172<sub>n</sub>  
 Hall, H. A., 373<sub>n</sub>  
 Hall, R. E., 81<sub>n</sub>  
 Hall Co., C. P., 28, 537  
 Halle, H. J., 390, 393  
 Hallett, R. L., 375  
 Halowax Corp., 222<sub>n</sub>  
 Hamilton, A., 8, 15  
 Hamilton, A. K., 162  
 Hamilton, H. W., 222<sub>n</sub>  
 Hamilton, J. M., 84  
 Hamilton By-Product Coke Co., 213-4  
 Hamilton & Co., A. K., 162<sub>n</sub>  
 Hamilton Coke & Iron Co., 217, 518  
 Hamilton Laboratories, 251<sub>n</sub>  
 Hamm Co., H., 519  
 Hammer, A. J., 361  
 Hammond, J. W., 319<sub>n</sub>  
 Hampden Paint & Chemical Co., 537  
 Hampton & Co., J. W., Jr., 13  
 Hancock, E. H., 373<sub>n</sub>  
 Hand, A. N., 411  
 \*Hand, C. N., 199\*, 224, 414  
 Hand Trading Co., 327<sub>n</sub>  
 Handel, G. F., 236  
 Handforth, S. L., 95  
 Handy, J. A., 153<sub>n</sub>  
 Hanks, W. V., 396  
 Hanna Furnace Co., 518  
 Hanson, E. R., 222  
 Harbison-Walker Refractories Co., 523  
 Harding, W. G., 3, 7-8, 15  
 Hardy, F., 361



Harkotsche Bergwerke u. Chemische Fabriken, 138  
 Harmon Color Works, 537  
 Harn, O. C., 375  
 Harriman & Co., W. A., 164*n*  
 Harrington, W. F., 60*n*, 239, 400, 550  
 Harris, H., 371  
 Harris, W., 165  
 Harrison, A. W. C., 362  
 Harrison, D. E., 129*n*  
 Harrison, J. G., 137, 146  
 Harrison, W., 360  
 Harrison Bros. & Co., 33, 36-37, 135, 301*n*  
 Harrow, B., 549  
 Harshaw Chemical Co., 134*n*, 183*n*  
 Harshaw, Fuller & Goodwin, 108  
 Hart, E., 346  
 Hartford Electric Light Co., 268  
 Hartogs, J. C., 380*n*  
 Hartong, R. C., 414  
 Hartsville Fertilizer Co., 519  
 Haskell, A. L., 420  
 \*Haskell, G. L., 155*n*, 166\*, 204, 550  
 \*Haskell, S. B., 310\*, 313, 317, 317*n*, 329  
 \*Haslam, R. T., 390\*, 396, 396*n*, 406, 549  
 Hass, H. B., 298*n*  
 Hasslacher, G. F., 60*n*  
 Haste, J. H., 189*n*  
 Hatch, B. F., 225  
 Haugen, G. N., 355  
 Hauser, E. A., 412, 426  
 Hawkes, A. W., 23-24, 26*n*, 345  
 Hawley, E. W., 359*n*  
 Hawn, R. J., 106*n*  
 Hayden, C., 99*n*  
 Hayden, Stone & Co., 98, 99*n*  
 Hayes, A. G., 191*n*  
 Haynes, R. A., 151-2, 154, 159  
 Haynes, W., 10*n*, 16, 23, 26, 26*n*, 47, 146, 186, 205-6, 225, 433, 433*n*, 434, 436*n*, 437, 437*n*, 504  
 Haynes & George Co., 116*n*  
 Hayward, G. E., 538  
 Hazard, C., 28  
 Hazen, M. S., 26*n*  
 Heald, K. C., 391  
 Heald Co., J. H., 422  
 Heath & Milligan Paint Manufacturing Co., 114*n*, 344*n*  
 Heather Co., 303  
 Hechenbleikner, I., 105  
 Heckel, G. B., 344, 373  
 Heckscher, A., 426  
 Hecla Mining Co., 372  
 Hedges-Walsh-Weidner Co., 94

Heflin, J. T., 321  
 Hegeler Zinc Co., 371*n*, 512  
 Heidelberg, M., 249  
 Heim, W. L., 172, 181, 185  
 Heinemann Chemical Co., 185  
 Helfrich, O. B., 166  
 Heller & Merz Co., 45, 257, 373*n*  
 Hemingway, F., 10*n*  
 Hemingway, Inc., Frank, 338  
 Henderson, W. F., 361  
 Hendrickson, B. V., 372  
 Henke Chemical Co., 537  
 Hennessy, H. A., 365*n*  
 Henry, L., 197*n*  
 Henry, S. C., 154  
 Henry, V., 412  
 Hercules Powder Co., 12, 35*n*, 39-40, 201, 231*n*, 350, 353, 356, 356*n*, 357*n*, 359, 360*n*, 513  
 Herold, P., 221*n*  
 Herreshoff, J. B. F., 101*n*  
 Herrick, H. F., 344*n*  
 Herrick, H. T., 273, 423, 428  
 \*Herrly, C. J., 167\*, 183  
 Herrmann & Co., Morris, 373  
 Herron, J. W., 417*n*  
 Herschkind, W., 126  
 Herty, C. H., 11, 29, 52, 201, 239, 299, 306, 390, 392, 433, 435*n*, 436*n*, 549  
 Hesse, B. C., 10  
 Heyden Chemical Company of America, 215, 253, 291, 373  
 Heyden Chemical Corp., 253-4, 271  
 Heyden Chemical Works, 254, 254*n*  
 Heyl, F. W., 252  
 Heyl, G. F. W. V., 253  
 Heyl Laboratories, 40, 253  
 Higbee, 341  
 Higgins, J. A., 255  
 Higgins, W., 38  
 Hildt, T., 289*n*  
 \*Hill, A. J., 247\*, 252  
 Hill's Son & Co., Edward, 115, 117  
 Hilo Varnish Corp., 360  
 Hilton, S. H., 282*n*  
 Hinds Co., A. S., 254  
 Hirschland, F. H., 141  
 Hirsch, J. H., 423*n*  
 Hitchcock, L. B., 350*n*, 361  
 \*Hitchner, L. S., 327\*, 333*n*, 336*n*, 345  
 Hoar, H. M., 62  
 Hobbs, F. W., 539  
 Hochstadter, I., 436  
 Hochwalt, C. A., 399-400, 407  
 Hodge, E., Jr., 210  
 Hoechst, *see* Farbwerke Hoechst  
 Hoff, C. M., 126

- Hoff Co., Johann, 231*n*  
 Hoffman, B. O., 259  
 Hoffman, C., 428  
 Hoffman-La Roche Chemical Works, 248, 285, 285*n*, 287, 289  
 Hofmann, A. W. von, 207  
 Hofmann, F., 411  
 Hoke, C. M., 549  
 Holden, H. C., 196  
 Holdermann, K., 539  
 Holdman, E. E., 357*n*  
 Holdsworth, J., 82  
 Holland, H., 387*n*  
 Holland, M., 432, 439  
 Holland Aniline Co., 229  
 Hollander, C. S., 145  
 Hollingsworth & Peterson, 115  
 Holloway, W. L., 80  
 Hollywood, J., 538  
 Holmes, A. A., 431*n*  
 Holmes, H. N., 83, 434  
 Holmes, R. C., 393  
 Holstein, P. F., 273, 330  
 Holstein, W. H., 87  
 Holter, W., 204  
 Holton, E. C., 346, 361  
 Holzverkohlungs Industrie A.-G., 184*n*  
 Homberg, F., 354  
 Home Fertilizer Co., 328  
 Home Guano Co., 512, 519  
 Hood Rubber Co., 213*n*  
 Hoodless, W. H., 166  
 Hooker, A. H., 110, 114, 330, 549  
 Hooker, A. H., Jr., 114*n*  
 Hooker, E. H., 26*n*, 28, 114*n*, 321, 330, 430*n*, 549  
 Hooker, R. W., 114*n*  
 Hooker Electrochemical Co., 35*n*, 87, 114, 116, 119, 125, 319, 413*n*, 426*n*, 430*n*, 522  
 Hooper, N. J., 192  
 Hoots, H. W., 331  
 Hoover, C. P., 145  
 Hoover, G. W., 281  
 Hoover, H., 8-13, 15, 61, 284, 344, 438  
 Hoover & Mason, 98  
 Hope, C. E., 79  
 Hope & Co., 324*n*  
 Hope Falls Logging Co., 178*n*  
 Hopkins & Co., J. L., 303*n*  
 Hopkinson, E., 412  
 Hopper, A. M., 27  
 Horan, C. F., 213*n*  
 Hord Color Products Co., 232  
 Hori, Y., 283  
 Hoshi Pharmaceutical Co., 284  
 Hosken, W., 284*n*  
 Hosken & Co., 284*n*, 285*n*  
 Hoskins, W., 549  
 Household Products Co., 290  
 Houts, C. A., 372*n*  
 \*Hovey, W. C., 167\*, 183  
 \*Howard, F. A., 390\*, 396*n*, 401-2, 403*n*, 406  
 \*Howard, G. C., 418, 423\*  
 Howard, H., 413*n*  
 Howard, Henry, 10*n*, 11, 122*n*, 123, 549  
 Howard & Sons, Ltd., 299  
 Howe, E. K., 323*n*  
 Howe, H., 304  
 Howe, H. E., 11, 154, 155*n*, 377, 388, 428, 432-3, 435*n*, 549  
 Howe, W. B., 323, 323*n*  
 Howell, W. H., 403*n*  
 Howes, A. P., 241  
 Howse, C. H., 265  
 Hoyt, L. F., 346  
 Hoyt, R. F., 99*n*  
 Huber, H. W., 417*n*  
 Huber, Inc., J. M., 415, 417*n*  
 Hubert's Malvina, Inc., 290  
 Hudson, R. M., 12*n*  
 Huggins & Sons, Jas., 254*n*  
 Hughes, A., 79  
 Hughes, B. C., 79*n*  
 Hughes, C. E., 6  
 Hughes, Rounds, Schurman & Dwight, 258  
 Huisking, C. L., 11  
 Huisking & Co., Charles L., 11  
 Humboldt Sulphur Co., 80  
 Humes, E., 13*n*, 63  
 Humphrey, I. W., 391*n*  
 Humphrey, W. E., 36, 344  
 Humphreys, R. E., 393  
 Humphreys Carbon Co., 415*n*  
 Hungarian Rubber Goods Co., 413  
 Huning, H. W., 259  
 Hunt, R., 403*n*  
 Hunt, S. B., 16  
 Hunter, M. A., 549  
 Huntington, W. D., 60*n*, 70*n*, 99*n*, 322*n*, 329, 549  
 Huntington Laboratories, 344*n*  
 Huntoon, M., 84  
 Hurley, J. F., 237  
 Hurley, T. L., 237  
 Hurley-Johnson Corp., 237  
 Hurl, P., 396*n*  
 Hutchens, F. C., 80  
 Hutchings, C. F., 130  
 Hutton, R. S., 427  
 Hutz, R., 235  
 Hyatt, J. W., 350

- Hycar Chemical Co., 413*n*  
 Hyde, A. T., 232  
 Hyde, E. P., 432  
 Hyde, J., 389  
 Hyde, R. W., 135*n*  
 Hyde, W., 229  
 Hydro Engineering & Chemical Co., 396*n*  
 Hydrocarbon Products Co., 211  
 Hydrox Chemical Co., 417  
 Hynson, Westcott & Dunning, 245, 250  
  
 I.G. Farbenindustrie, 38, 49, 51-53, 57, 59-60, 135*n*, 141, 171-2, 174, 234-6, 286, 313-4, 317, 343, 368, 372, 395-6, 404, 506  
 Iliff-Bruff Chemical Co., 104  
 Illinois Glass Co., 420  
 Illinois Zinc Co., 371*n*, 512  
 Imbrie, A. W., 539  
 Imison, C. S., 83  
 Imperial Chemical Industries, Ltd., 38, 55, 57-59, 314, 368*n*, 395, 507-8  
 Imperial Color Works, 374  
 Imperial Paper & Color Corp., 374*n*  
 Imperial Rayon Corp., 385*n*  
 Indian Refining Co., 404  
 Industrial Chemical Co., 158*n*  
 Industrial Chemical Corp., 264  
 Industrial Chemical Manufacturing Co., 164  
 Industrial Dyestuff Co., 229  
 Industrial Fibre Corporation of America, 378-9  
 Industrial Fibre Throwing & Dyeing Co., 379  
 Industrial Rayon Corp., 378-9, 381, 388, 388*n*, 547  
 Industrial Solvents Corp., 192  
 Industrial Trust Co., 97*n*  
 Ingram & Co., F. F., 285*n*  
 Inland Steel Co., 209, 518  
 Inland Tar Co., 537  
 Inman, M. T., 156  
 Innis, Speiden & Co., 119, 120*n*, 342  
 Inspiration Consolidated Copper Co., 341*n*  
 Interchemical Corp., 253*n*, 427  
 International Acceptance Bank, 236  
 International Agricultural Corp., 97, 97*n*, 98, 101, 322*n*, 327, 327*n*, 434, 512, 518-9  
 International Bergin Co., 395  
 International Cellucotton Products Co., 303*n*  
 International Chemical Co., Ltd., 290, 344*n*  
 International Coal Products Co., 140*n*  
 International Combustion Engineering Corp., 212, 217  
 International Combustion Tar & Chemical Corp., 212, 218  
 International Harvester Co., 518  
 International Lead Refining Co., 370*n*  
 International Mercury Corp., 268  
 International Mining & Chemical Corp., 140*n*  
 International Smelting & Refining Co., 334, 337, 341*n*  
 International Solvents Co., 165  
 Interstate Sanitation Co., 344*n*, 345  
 Interwoven Hosiery & Co., 381  
 Investment Co., 365  
 Inyo Chemical Co., 118, 140*n*, 522  
 Io-Dow Chemical Co., 267  
 Iowa Soda Products Co., 129  
 Ironton By-Product Coke Co., 212  
 Irvine, Sir J., 433  
 Isakovics, A. von, 297  
 Isco Chemical Co., 119, 125, 522  
 \*Isermann, S., 10*n*, 229, 233, 295\*, 296-7, 301*n*  
 Ising Corp., C. E., 192, 284*n*  
 Isobe, F., 90  
 Isom, E. W., 393  
 Ittner, M. H., 153*n*, 154, 155*n*, 297, 549  
 Ives, C. L., 322*n*  
 Ivey, A. L., 322*n*  
  
 Jackson, D. D., 549  
 Jackson, L. E., 343*n*, 347  
 Jackson & Co., Ellis, 116  
 Jackson Fertilizer Co., 512, 519  
 Jackson Iron & Steel Co., 518  
 Jacob, K. D., 106*n*, 110, 326  
 Jacobs, S. W., 120*n*  
 Jacobs, W. A., 249  
 \*Jacobson, B. H., 134, 135\*, 219  
 \*Jaeger, A. O., 38\*, 45, 69-70, 83, 219*n*  
 James, J. H., 156  
 Jardine Mining Co., 334, 338  
 Jarecki Chemical Co., 512, 519  
 Jax Plantfood Co., 106  
 Jayne, D. W., 211*n*, 225  
 Jayne, H. W., 211*n*  
 Jayne & Sidebottom, 211  
 Jeffcott, R. C., 45  
 Jefferson Distilling & Denaturing Co., 158*n*, 164, 164*n*  
 Jefferson Fertilizer Co., 512  
 Jell, A. P., 164  
 Jenkel, L., 296  
 Jenkins, N. S., 303  
 Jenkins, O. P., 129

Jenkins, R. L., 225  
 Jennings, J. M., 396  
 Jennison-Wright Co., 537  
 Jessup & Moore Paper Co., 522  
 J. H. R. Products Co., 137-9  
 Johns, C. O., 403*n*  
 Johnson, C. A., 237  
 Johnson, C. R., 416  
 Johnson, H. A., 427  
 Johnson, H. M., 362  
 Johnson, J. T., 380*n*  
 Johnson, T. B., 251-2, 256, 435*n*, 549  
 Johnson & Co., Chas. A., 237  
 Johnson & Johnson, 288  
 Johnson Rayon Mills, A. M., 388, 547  
 Johnston, A. C., 205, 361  
 Jones, C. L., 428  
 Jones, C. W., 267  
 Jones, E. M., 108  
 Jones, L. C., 86*n*, 90, 92*n*, 93  
 Jones, L. M., 29  
 Jones Chemical Co., 267  
 Jones-Dabney Co., 361  
 Jordan, F. F., 203  
 Jordan Co., Stanley, 303*n*  
 Josephson, W. L., 426  
 Josey Guano Co., N. B., 519  
 Joyce, W. I., 238  
 Judson, W., 78  
 Judy, H. A., 80  
 Jumeau, P., 109  
 Jung, G., 79

# Kalamazoo Vegetable Parchment Co., 387

Kalbfleisch, A. C., 26*n*, 437*n*  
 Kalbfleisch, F. H., 44  
 Kalbfleisch Bauxite Co., 44  
 Kalbfleisch Corp., 23, 44-45, 135, 257, 512, 523  
 Kali-Chemie A.-G., 55*n*  
 Kali Syndikat, 323  
 Kalish, J., 109  
 Kalish, V. H., 330  
 Kalle & Co., A.-G., 51-52, 232, 240*n*  
 Kalman, N., 538  
 Kamm, O., 436  
 Kanawha Valley Power Co., 194  
 Kanawha Valley Water Co., 224*n*  
 Kane, R. M., 154  
 Kao, C. H., 284*n*  
 Karolith Corp., 354  
 Karpeles, S. L., 375  
 Karpen & Bros., S., 349*n*  
 Katzenstein, 538  
 Kay, A. G., 156  
 Kay Laboratories, Inc., 157

Kay Research Co., 156-7  
 Kayton, H. L., 356*n*  
 Keasby & Mattison Co., 271  
 Keating, J., 27  
 Keating, R. M., 341*n*  
 Keenen, F. G., 317*n*, 330  
 Keery, A. J., 182*n*, 185  
 Keery Co., Thomas, 174, 181, 185  
 Kehoe, R. A., 403*n*  
 Kehoe, R. D., 232  
 Keller, J. J., 238*n*  
 Keller, R. J., 238*n*  
 Keller & Co., John J., 237*n*  
 Kelley, C. F., 340  
 Kelley, P., 128  
 Kellogg, H. W., 130  
 Kelp Products Co., 354  
 Kemmler, C. W., 79  
 Kempton, W. H., 544  
 Kendall, J., 435*n*, 549  
 Kennecott Copper Corp., 340, 341*n*  
 Kennedy, A. L., 354  
 Kennedy, A. M., 336, 346  
 Kennedy, P. E., 361  
 Kent Color Corp., 537  
 Kentucky Alcohol Corp., 158*n*, 162-3, 163*n*, 165, 181*n*, 203  
 Kentucky Color & Chemical Co., 222, 232-3, 373  
 Keratol Co., 39  
 Kerin, A. J., 538  
 Kerin Manufacturing Co., 45*n*, 231, 538-9  
 Kerr, R. H., 145  
 Kessler, J. M., 166, 204  
 Kessler, R., Jr., 201  
 Kessler Chemical Corp., 165, 204, 271, 298, 537  
 \*Kettering, C. F., 204, 260*n*, 261-2, 391\*, 397, 397*n*, 399, 401-2, 403*n*, 404, 406  
 Keyes, D. B., 200*n*, 205  
 Keystone Arsenic Co., 335  
 Keystone Products Co., 420*n*  
 Keystone Wood Chemical & Lumber Corp., 173*n*, 180  
 Keystone Wood Products Co., 183  
 \*Kharasch, M. S., 247\*, 251  
 Kienle, J. A., 23, 118, 126, 503-4  
 Kienle, R. H., 358*n*, 362  
 Kies, W. S., 191*n*  
 Kilbreth, J. T., 79  
 Killeffer, D. H., 83, 95, 110, 167, 186, 199*n*, 204-5, 225, 242, 255, 272, 293, 306, 346, 361-2, 389, 406-7, 426-8, 440  
 Killheffer, E. H., 205, 239, 241, 550  
 Kimberly-Clark Co., 522

- Kinetic Chemicals, Inc., 399*n*  
 King, G., 375  
 King, E. & F., 116  
 King Chemical Co., 45*n*, 231, 519  
 Kingsley, E. D., 119, 126  
 Kingsley, G. E., 371  
 Kinneburgh, M., 237  
 \*Kinsman, J. W., 327\*, 343*n*, 347, 426  
 Kirby, A. P., 82  
 Kirby, F. M., 82  
 \*Kirkpatrick, S. D., 204, 384*n*, 389, 406-7, 438\*, 439  
 Kirsopp, E. C. B., 357  
 Kissel, A., 355*n*  
 Kitchen, E. M., 273  
 Klaustermeyer, C. H., 371*n*  
 Klein, J., 12, 12*n*, 13, 33*n*  
 Klein, S., 158*n*, 163  
 Klencke, H., 71*n*  
 Klepetko, E., 98*n*  
 Kline, C. M., 27*n*, 291*n*  
 Klipstein, A., 26*n*  
 Klipstein, E. C., 222*n*  
 Klipstein, E. H., 232*n*, 539, 550  
 Klipstein, K. H., 146, 232*n*  
 Klipstein & Co., A., 27, 45*n*, 129, 222*n*, 232, 240*n*  
 Klipstein & Sons, E. C., 119*n*, 134, 232, 539  
 Klotz, J. R. M., 218*n*  
 Klugh, B. G., 106, 110  
 Knapp, D. A., 268  
 Knight, C. H., 419*n*  
 \*Knight, H. G., 386, 438  
 Knistern, L. T., 185  
 Knistern, W. W., 92*n*  
 Knox & Morse, 254*n*  
 Knoxville Fertilizer Co., 519  
 Kober Chemical Co., 537  
 Koblegard, T. F., 415*n*  
 Kochs, A., 107  
 Koeff, M., 384  
 Köln-Rottweil A.-G., 38, 53  
 Koenigs, F., 380*n*  
 Koethen, F. L., 110  
 Koganei, R., 428  
 Kohnstamm & Co., H., 373  
 Kolb, C. M., 427  
 Kolb, L., 292  
 Kolynos Co., 303  
 Koppe, P., 221*n*  
 Koppers Co., 80-81, 81*n*, 84, 209-10, 210*n*, 212-3, 217, 222, 313, 434  
 Kosmos Carbon Co., 415, 415*n*  
 Kraemer, E. O., 434  
 Kraft Cheese Co., 424  
 Kramer, R. L., 262  
 Krase, N. W., 186  
 Kratz, G. D., 411, 426  
 \*Kraus, C. A., 402, 406\*  
 Krebs Pigment & Chemical Co., 37, 369, 373, 524  
 Kreiss, A. L., 325  
 Kremens, A., 249*n*  
 Kreps, T. J., 62  
 Kresel, I. J., 240  
 Kress, O., 419  
 Kressman, F. W., 356*n*  
 Kuhlmann, F., 91  
 Kuhnert Syndicate, 522  
 \*Kunz, E. C., 294\*, 301  
 Kunze, R., 323*n*  
 Kurz-Kasch Co., 349  
 Kuttroff, A., 235, 236*n*  
 Kuttroff, Pickhardt & Co., 174, 234-5, 317  
 Kutz, M., 437  
 KYW (Radio Station), 5  
 La Cellophane Co., 351  
 LaForge, F. B., 361, 544  
 La Soie de Chatillon, 381  
 LaVallee, C. J., 538  
 LaVallee, G., 538  
 LaWall, C. H., 252  
 Laboratories Naline, 250  
 Laclede-Christy Clay Products Co., 523  
 Lacquer & Chemical Corp., 158  
 Lacquer Chemicals, Inc., 181, 360  
 Lai, C. F., 420  
 Laist, F., 370  
 Lake Charles Rice Milling Co., 387  
 Lamb, A. B., 549  
 Lamborn, L., 436, 439, 549  
 Lamot, Corliss & Co., 289*n*  
 Lancaster Bone Fertilizer Co., 328  
 Lancaster Chemical Co., 512  
 Landecker, M., 354  
 \*Landes, G. B., 182\*, 196  
 Landis, W. S., 86*n*, 92, 92*n*, 93*n*, 313, 434  
 Lane, F. W., 256  
 Lang, W. B., 325*n*  
 Langenbruch, W., 384  
 Langmuir, A. C., 549  
 Langmuir, I., 399, 407, 433, 549  
 Larison, E. L., 109  
 Larkin, J. D., 434  
 Larned Co., 290  
 Larson, A. T., 86-87, 194  
 Larsson, M., 95  
 Larvex Corp., 344*n*  
 Lasdon, W. S., 290  
 Lasker, E., 191*n*

- Lauer, C. N., 289<sub>n</sub>  
 Laurel Oil & Fertilizer Co., 512, 519  
 Laurie, J. W., 203<sub>n</sub>  
 Lauro, M., 366<sub>n</sub>  
 Laury, N. A., 128  
 Lautaro Nitrate Co., Ltd., 316  
 Lautaro Nitrate Corp., 316<sub>n</sub>  
 Lavanburg Co., Fred L., 373  
 Lawrence, C. C., 381<sub>n</sub>  
 Lawrence, H. M., 109  
 Lawrence, W. J., 420  
 Lawson, A. M., 103  
 Layfield, W. A., 385  
 Layraud, E., 248<sub>n</sub>  
 Layton Pure Food Co., 424  
 Lazote, Inc., 37, 87-88, 172, 434, 506, 537  
 Le Châtelier, H. L., 170<sub>n</sub>  
 Le Cornec, J., 323  
 Leackman, T., 325  
 Leake, J. P., 403  
 Leamon, W. G., 394  
 Leathers, W. S., 403<sub>n</sub>  
 Leblanc, N., 55, 58, 128  
 Lederle Laboratories, Inc., 46<sub>n</sub>  
 Ledoux, A. D., 82, 433<sub>n</sub>  
 Lee, J. A., 427  
 Lee, M. du P., 352<sub>n</sub>  
 Lee, R. E., 549  
 Lee, Higginson & Co., 380<sub>n</sub>  
 Leeds & Northrup Co., 92<sub>n</sub>  
 Legg, D. A., 188  
 Lehman, P., 258  
 Lehman Bros., 258  
 Lehn, L., 254  
 Lehn & Fink, 254  
 Lehn & Fink Products Co., 254, 277  
 Leith, C. K., 433  
 Leland, H. M., 324  
 Lenher, V., 204, 206, 399, 407  
 Lennig & Co., Chas., 512, 523  
 Leonard, V., 251, 256  
 Leopold, O. F., 303<sub>n</sub>  
 Leslie-California Salt Co., 264  
 Lesser, R. W., 135  
 Lesser & MacGruer, 135  
 Levenhagen, R. W., 373<sub>n</sub>  
 Levering, J. H., 321<sub>n</sub>  
 Levey, H. A., 428  
 Levin, M., 163, 165  
 Levinstein, Ltd., 57  
 Levinstein & Co., I., 236  
 Lewes Fertilizer Co., 328  
 Lewis, H. F., 419  
 Lewis, W. A., 292  
 Lewis, W. K., 394  
 Lewis, W. L., 252  
 Lewis & Bro. Co., John T., 373  
 Lewis Manufacturing Co., F. J., 211-2  
 L. F. Medicine Co., 290  
 Liberty Carbon Co., 415<sub>n</sub>  
 Lichtenstein, A. F., 239  
 Lidbury, F. A., 108-9, 549  
 Lidholm, J. H., 318-9  
 Liebenguth, L., 381<sub>n</sub>  
 Liefmann, R., 49-50, 50<sub>n</sub>  
 Light, A. B., 281<sub>n</sub>  
 Lightfoot, E. E., 344<sub>n</sub>  
 Liljenroth, F. G., 95, 107  
 Lilly & Co., Eli, 218<sub>n</sub>, 248, 251, 255, 278, 282, 283<sub>n</sub>, 284, 537, 540  
 Limestone Fertilizer Co., 328  
 Lind, C. O., 27  
 Linde Air Products Co., 194  
 Linder, W. V., 159<sub>n</sub>  
 Linder & Meyer, 115  
 Lindsay, W. G., 351  
 Lindsley, S., 300  
 Liquid Carbonic Corp., 426  
 Litchfield, L., Jr., 146  
 Little, A. D., 439  
 Little, Inc., Arthur D., 193, 351  
 Liverpool Salt & Coal Co., 265  
 \*Lloyd, S. J., 326\*, 336, 346  
 Loasby, A. W., 163  
 Lockwood, J. E., 356<sub>n</sub>, 357<sub>n</sub>  
 Loengard, R., 141  
 Logan, W. B., 356  
 Logue, P., 104  
 Long, J. S., 375  
 Long, W. B., 331  
 Long Island Color & Chemical Corp., 537  
 \*Longstreth, B., 407\*, 410  
 Loomis, C. C., 354  
 Loomis, N. E., 407  
 Loomis, Stump & Banks, 341  
 Los Angeles Chemical Co., 524  
 Lotte, E. F. L., 300  
 Lougee, E. F., 361  
 Louisiana Carbon Co., 415<sub>n</sub>  
 Louisiana Chemical Co., 29, 71, 513  
 Louisiana Gas Products Corp., 415<sub>n</sub>  
 Lourie, H. L., 549  
 Loutrel, L. F., 182  
 Louwrenburgh, 199<sub>n</sub>  
 Lowe Bros. Paint Co., 254<sub>n</sub>  
 Lowell Fertilizer Co., 512, 519  
 Lowenstein, S., 357<sub>n</sub>  
 Lowman, S., 159  
 Lowy, F., 303  
 L. & R. Organic Products Co., 240  
 Lucas & Co., John, 344-5  
 Lucas Co., Spencer, 373, 537

- Lucas Kil-Tone Co., 336*n*, 345  
 Lucidol Corp., 537  
 Luckhardt, A. B., 269, 273  
 Ludwig, B. A., 233, 234*n*, 235  
 Luer, A., 137  
 Lufkin, E. C., 74  
 \*Lundy, W. T., 54\*, 75-76, 84  
 Lustron Co., 382*n*  
 Lynch, F. J., 302*n*  
 Lyon, C. E., 13*n*  
 \*Lyon, L. (Atlas Powder Co.), 375\*  
 Lyons, R. E., 221  
  
 \*McAfee, A. M., 132-4, 135\*, 219, 394  
 McBride, R. S., 95, 224, 314*n*, 330  
 McCabe Chemical Co., 512  
 McCabe Fertilizer Co., 327*n*, 519  
 \*McCartney, F. L., 10*n*, 23, 278\*, 504  
 McCarty, E., 367  
 McClellan, G. S., 62  
 McClellan, W., 320-21  
 McClintock, E. I., 343*n*  
 McClure, H. B., 197*n*  
 McConnell, W. J., 403  
 McCormack, J. A., 182*n*, 185  
 McCormack, J. H., 357*n*  
 McCoy, E., 189*n*  
 McCoy, G. W., 240, 539  
 McCullough, R., 225  
 McCurdy, J. L., 291*n*  
 McDaniel, J. C., 189*n*  
 McDonough, F. J., 291  
 McDougall, J., 318  
 MacDowell, C. H., 62, 68*n*, 71*n*, 101*n*,  
 109, 317*n*, 320, 322*n*, 433, 439, 541  
 McEldowney, H. C., 380*n*  
 McGavack, J., 412*n*  
 McGoldrick, J. E., 13*n*  
 McGovern, J. P., 151, 152*n*, 153*n*, 167  
 McGowan, Sir H., 57*n*  
 McGraw-Hill Publishing Co., 11  
 \*MacGregor, F. S., 55\*, 88  
 MacGruer, J. A., 135  
 McGuire, F. J., 324  
 \*McGuire, J. H., 246\*, 254*n*  
 McIlravy, W. N., 313  
 McIndoe, W. C., 146  
 McKay, A. J., 371*n*  
 McKee, R. H., 201, 549  
 McKenzie, J. C., 320  
 McKesson, D., 290  
 McKesson, I., 290  
 McKesson, John, 290  
 McKesson & Robbins, 253, 276, 290-91,  
 410*n*  
 McKinley, W., 7  
 \*McLaughlin, G. D., 422, 423\*  
  
 McLaughlin, J. W., 196  
 McLellan, W. W., 381  
 McLellan Stores Co., 381  
 MacMullin, R. B., 110  
 MacNair, I. P., 307  
 McNary, C. L., 355  
 McNulty, J. H., 365  
 McNutt, V. H., 326  
 McPherson, C., 264  
 McPherson, W., 399  
 McVicar, N., 69  
 Maas, A. R., 102, 102*n*  
 Maas Chemical Co., A. R., 28, 102  
 Maas & Waldstein Co., 189*n*, 190, 192  
 Mace, C. A., 60*n*, 239, 550  
 Macgregor, D. H., 50*n*  
 Machado, Pres., 161  
 Macher & Sons, Wm., 373  
 Mackinnon, H. D., 428  
 Macy & Co., R. H., 418  
 Madden, M. B., 321  
 \*Maercky, P. G., 54\*, 75  
 Maekubee (Holland), 380*n*  
 Magnetic Pigment Co., 372  
 Magnusson, J. P., 328  
 Mains, G. H., 350, 544  
 Maisner, H., 83  
 Majestic Distilling Co., 189  
 Mallinckrodt, E., 258-9, 435  
 Mallinckrodt, E., Jr., 259, 259*n*  
 Mallinckrodt Chemical Works, 27, 35*n*,  
 104-5, 142, 249, 258, 259*n*, 270-71,  
 282, 285*n*, 287-8  
 Maltby, C., 139  
 Mancini, U., 381*n*  
 Mandeville Mills, 512, 519  
 Manhattan Electric Supply Co., 41  
 Manhattan Medicine Co., 290  
 Manhattan Rubber Manufacturing Co.,  
 410*n*  
 Manley, F. T., 393  
 Mann, M. D., Jr., 193, 201  
 Manning, P. D. V., 126, 140  
 Manning, V. H., 390  
 Mansfield, G. R., 325*n*, 331, 433*n*  
 Mapes, J. J., 317, 541  
 Maple Chemical Co., 537  
 Marathon Corp., 418*n*  
 Marathon Paper Mills, 418  
 Marble-Nye Co., 116  
 Marcovitch, S., 346  
 Marietta Dyestuffs Co., 229, 234, 537,  
 539  
 Marietta Paint & Color Co., 538  
 Marietta Refining Co., 538  
 Marimon, J., 372*n*  
 Marine Chemicals Co., Ltd., 140

- Marks, A. H., 409  
 Marks, L. H., 13, 63, 158, 253  
 Marsh, C. T. N., 145  
 Marsh, H. S., 72  
 Marsh, W. J., 114  
 Marshall, A. E., 95, 549  
 Marshall, J., 362, 399  
 Martenet, S. J., 322*n*  
 Martin, H. S., 109  
 Martin, O. V., 265  
 Martin, T. W., 336  
 Martin Chemical Co., 265  
 Martin & Co., L., 211*n*  
 Marting Iron & Steel Co., 518  
 Marvin, T., 362  
 Marx, A. H., 74*n*  
 Marx, C., 361-2  
 Marx Color & Chemical Co., Max, 373  
 Mason, D. B., 83  
 Mason, W. H., 419  
 Mason By-Products Co., 426*n*, 537  
 Mason Fibre Co., 419  
 Masonite Corp., 419  
 Massasoit Manufacturing Co., 387  
 Massillon Stone & Fire Brick Co., 523  
 Masters, C. L., 232*n*  
 Mathieson Alkali Works, 23, 25, 27-28, 35*n*, 42, 85, 87, 89*n*, 90, 93, 113-6, 118, 123, 125, 134*n*, 171*n*, 175, 191*n*, 259, 306, 394, 434, 437-8, 521-2  
 Matos, L. J., 549  
 Matthews, J. M., 238  
 Matthews, W. C., 388  
 Matthews, W. H., 172, 178, 179*n*  
 Matthiessen & Hegeler Zinc Co., 371*n*, 512  
 Mauritho, O. L., 222  
 Mavlankar, K. B., 42  
 Maxim, H., 333  
 Maxwell, A. M., 402, 403*n*  
 \*May, B. M., 342\*, 351, 385*n*, 389  
 \*May, O. B., 231  
 May, O. E., 423, 428  
 May, Inc., Otto B., 231*n*  
 May & Baker, Ltd., 249  
 May Chemical Corp., 231*n*  
 May Chemical Works, 44, 45*n*, 231, 259  
 Maybank Fertilizer Co., 512, 519  
 Mayer Alcohol Co., S. M., 165  
 Maynard, H., 142*n*  
 \*Maynard, P., 421, 422\*  
 Maywood Chemical Works, 255, 271, 283, 286, 305  
 M. C. S. Chemical Co., 259  
 Mead Pulp & Paper Co., 418*n*  
 Meade, C. A., 10*n*  
 Meadows, E. H., 322*n*  
 Meadows Fertilizer Co., 322*n*, 328  
 Mees, C. E. K., 433*n*  
 Mehren, E. J., 63  
 Meigs, Bassett & Slaughter, 300  
 Meikleham, T. M. R., 359*n*  
 Melba Manufacturing Co., 303  
 Melchett, Lord, *see* Mond, Sir A.  
 Melco Chemical Co., 193*n*  
 Mellon A., 8, 13-14, 100, 152-5  
 Melum, H. A., 373*n*  
 Melville, W. R., 174, 181*n*  
 Melvin, J. B., 355*n*  
 Memminger, C. G., 107*n*  
 Memphis Oxygen Co., 41  
 Memphis Power & Light Co., 319  
 Mennen Co., 278  
 \*Mente, E. W., 129*n*, 134\*  
 Mercantile-Commerce Bank & Trust Co., 43*n*  
 Merchants Chemical Co., 268*n*  
 Merchants' Feed & Phosphate Co., 512  
 Merchants' Fertilizer & Phosphate Co., 322*n*, 512, 519  
 Merchants & Planters Oil Co., 365*n*  
 Merck, G., 257-8  
 \*Merck, G. W., 258, 263\*, 265, 549  
 Merck, E. (firm), 247, 257  
 Merck & Co., 12, 142, 232*n*, 247, 249, 254, 257-8, 270-71, 273, 282-3, 285, 285*n*, 288, 290, 305, 512  
 Meridian Fertilizer Factory, 322*n*, 327*n*, 512, 519  
 Mering, J. von, 247  
 Meriwether, E. C., 356  
 Merrell Co., Wm. S., 192, 218*n*, 282  
 Merrill, H., 233  
 Merrill, T. S., 401  
 Merrill, W. D., 117  
 Merrimac Chemical Co., 12, 23, 35*n*, 42, 94*n*, 122*n*, 123, 135, 192, 204, 257, 353, 512-3, 523  
 Merwin, W. J., 172*n*, 174, 182*n*, 185, 186  
 Merz, A., 10*n*, 60*n*, 61*n*, 146, 239, 274*n*, 302*n*, 549-50  
 Merz, A. R., 104, 106*n*  
 Metal & Thermit Corp., 141  
 Metallgesellschaft A.-G., 82  
 Meteor Products Co., 108  
 Mettler, J. W., 381  
 Metts, W. B., 322*n*  
 Metz, H. A., 233, 234*n*, 235, 235*n*, 236*n*, 239, 282, 539, 549  
 Metz & Co., H. A., 233, 240, 248, 539  
 Metz Laboratories, Inc., H. A., 135, 248-50, 253, 255



- Metzger, F. J., 431*n*  
 Meyer, A., 537  
 Meyer, E., 40*n*  
 Meyer, K. H., 535  
 Meyer, V., 207  
 Meyer, Wilson & Co., 29  
 Meyers, H. H. 68*n*  
 Meyers, R., 63  
 Meyers, W. S., 314  
 Meyerson, H. W., 360  
 Miami Paper Co., 522  
 Mica Roofing Co., 211*n*  
 Michigan Alkali Works, 35*n*, 115, 117, 129*n*, 212, 521  
 Michigan Chemical Co., 165  
 Michigan Electrochemical Co., 124  
 Michigan Northern Power Co., 41  
 Michigan Ox-hydric Co., 41  
 Michigan Paper Co., 387  
 \*Middleton, G. W., 374\*, 385  
 \*Midgley, T., Jr., 261, 391\*, 397-402, 403*n*, 406-7, 425  
 Midland Chemical Co., 137*n*  
 Midwest Dye & Chemical Co., 129  
 Miles, G. W., 351  
 Millard, C. W., 549  
 \*Miller, C. W., 54\*, 82, 99, 549  
 Miller, E., 256  
 Miller, E. B., 99*n*, 406  
 Miller, M. B., 404  
 Miller, S. P., 216  
 Miller, T. G., 540  
 Miller, T. W., 8, 539  
 Miller, W., 392*n*, 394, 406  
 Miller Fertilizer Co., 327*n*, 328, 519  
 Miller Minerals Corp., R. K., 137  
 Milligan, C. H., 400  
 Milliken, G., 381*n*  
 Milliken, R., 390  
 Milliken & Co., John T., 259  
 Mills, J. E., 346  
 Mills, W. G., 71  
 Minaeff, M. G., 347  
 Miner, C. S., 350, 361, 544-5  
 Miner, H. H., 181*n*  
 Miner, H. S., 549  
 Miner-Edgar Co., 163*n*, 174, 181, 185*n*, 192  
 Miner Laboratories, 350, 359*n*, 544  
 Mineral Point Zinc Co., 524  
 Mineral Refining & Chemical Corp., 367, 372  
 Minerals Separation North American Corp., 98  
 Mississippi River Fuel Corp., 416  
 Misslin, E. E., 236  
 Missouri Land Co., 77  
 Mitchell, C. E., 236  
 Mitchell, C. T., 330  
 Mitchell, H. J., 57*n*, 507  
 Mitchell, H. R., 325  
 Mittasch, A., 171*n*  
 Mittnacht, A., 402  
 Moffat, F. M., 422  
 Moffett, J. A., Jr., 402  
 Molasses Distributors Corp., 165  
 Monarch Chemical Co., 103, 124, 424  
 Mond, Sir A., 56, 57*n*, 59, 262  
 Mond, H., 57*n*  
 Mond, L., 56  
 Mond Nickel Co., 58  
 \*Monitz, A. J. L. (American Enka Corp.), 374\*  
 Monrad, C. C., 225  
 Monsanto Chemical Co., 42*n*  
 Monsanto Chemical Works, 23, 33, 35*n*, 42-43, 69-70, 72, 83, 94*n*, 104*n*, 106*n*, 135, 212, 214*n*, 215, 217, 220-21, 254-5, 257, 259, 271, 280, 286-7, 299*n*, 300, 304-6, 354, 370, 414, 511-3, 522  
 Monsanto Chemical Works, Ltd., 42  
 Montague, G. H., 323  
 Montecatini, 58  
 Montezuma Fertilizer Co., 519  
 Moody, H. R., 549  
 Moody, Seagraves & Co., 77*n*  
 Mooers, C. A., 316  
 Moore, E. K., 375  
 Moore, H. C., 541  
 Moore, H. K., 432, 549  
 Moore, L. P., 546  
 Moore, R. J., 201*n*  
 Moore, W., 333, 437  
 Moore, W. C., 330  
 Moore & Co., Benjamin, 366, 546  
 Moorman Manufacturing Co., 518  
 Morana, Inc., 192, 296, 302  
 Moraw, H. O., 427  
 Morgan, J. P., 36  
 Morgan, L., 549  
 Morgan, W. L., 427  
 Morgan & Co., J. P., 383*n*  
 Morgan & Son, Frank E., 540  
 Moritz, A. J. L., 380*n*  
 Morrell, G., 354  
 Morris, H. M., Jr., 240-41  
 Morris, W. C., 313  
 Morris Fertilizer Co., 512, 519  
 \*Morrison, A. C., 6\*, 11-12, 15*n*, 16, 60*n*, 61, 61*n*, 63, 550  
 Morrison, C. L., 356*n*  
 Morrison, R. C., 415  
 Morrison Co., 356*n*  
 Morrow, L. C., 110

- Morton Salt Co., 264  
 Mory, A. V. H., 550  
 Mother Lode Coalitions Mines Co., 341<sub>n</sub>  
 Mothwurf, A., 380, 384  
 Mott, C. S., 401  
 Mount, W. D., 118  
 Mountain Copper Co., Ltd., 512, 519  
 Mudd, S. W., 75  
 Müller-Cunradi, M., 404  
 Muggleton, G. D., 202  
 Mulford Co., H. K., 289  
 Mulliken, H. S., 314<sub>n</sub>  
 Mullin, C. E., 16, 389  
 Mum Manufacturing Co., 290  
 Munch, J. C., 287  
 Murchison, C. T., 29  
 Murdock, H. R., 427  
 Murphy, W. J., 171<sub>n</sub>  
 Murphy & Co., G. M. P., 95  
 Murphy Varnish Co., 357, 361  
 Murray, A., 361  
 Murrill, P. I., 427  
 Muscle Shoals Fertilizer Co., 321  
 Muspratt, J., 55<sub>n</sub>  
 Muspratt, Sir M., 57<sub>n</sub>  
 Musterole Co., 537  
 Mutual Chemical Co., 33, 35<sub>n</sub>, 142, 512  
 Mutual Fertilizer Co., 322<sub>n</sub>, 327<sub>n</sub>, 512, 519  
 Myers, C. N., 539  
 Myles Salt Co., Ltd., 129, 518  
  
 Nagai, 283  
 Nagelvoort, A., 437  
 Naphthalene Products Co., 222  
 Napon Rayon Corp., 385, 547<sub>n</sub>  
 Naramore, C., 397<sub>n</sub>  
 Nash, J. C., 356<sub>n</sub>  
 Nashville Industrial Corp., 378  
 National Acetate Silk Co., 384  
 National Agrol Co., 215<sub>n</sub>  
 National Ammonia Co., 37, 88  
 National Aniline & Chemical Co., 40, 45, 69, 104<sub>n</sub>, 125<sub>n</sub>, 135, 220, 231, 233, 237<sub>n</sub>, 253, 259<sub>n</sub>, 260<sub>n</sub>, 410-11, 414, 419<sub>n</sub>  
 National Bearing Metals Corp., 43<sub>n</sub>  
 National Carbon Co., 197, 396<sub>n</sub>  
 National Carbonic Gas Co., 300  
 National Chemical Co., 335, 338  
 National Chromium Corp., 142  
 National City Bank, 236, 380<sub>n</sub>, 383<sub>n</sub>  
 National City Co., 36<sub>n</sub>, 236  
 National Coal Tar Co., 211<sub>n</sub>  
 National Distillers' Products Corp., 162-3, 165, 193  
  
 National Electrolytic Co., 130, 130<sub>n</sub>  
 National Ferrite Co., 372  
 National Gold Arsenic Corp., 335  
 National Gum & Mica Co., 538  
 National Industrial Alcohol Co., 165  
 National Kellastone Co., 265  
 National Lead Co., 367-8, 374, 375  
 National Pigments & Chemical Co., 524  
 National Silk Dyeing Co., 300  
 National Sugar Refining Co., 192<sub>n</sub>  
 National Ultramarine Co., 45<sub>n</sub>, 233, 373  
 National Zinc Co., 72, 299<sub>n</sub>, 513  
 National Zinc Ore Separating Co., 513  
 Natural Gas Products Co., 415, 415<sub>n</sub>  
 Natural Products Refining Co., 142  
 Natural Soda Products Co., 118, 522  
 Naugatuck Chemical Co., 412<sub>n</sub>, 413-4, 512  
 Naval Stores Export Corp., 355  
 Naval Stores Marketing Corp., 355  
 Neckar Salt Union, 50  
 Nederlandsche Kininefabriek, 284, 285<sub>n</sub>  
 Nederlandsche Kunstzydefabriek, 380  
 Neff, A., 428  
 Neiman, H. S., 549  
 \*Nelson, O., 415, 422\*  
 Nelson, W. B., 225  
 Nelson, W. G., 186  
 Nemzek, L. P., 365<sub>n</sub>  
 Neron, E., 16  
 Netzen, C., 397<sub>n</sub>, 398  
 Neuls, J. D., 342  
 Nevada Consolidated Copper Co., 341<sub>n</sub>  
 Neville, E. L., 281<sub>n</sub>  
 Neville Chemical Co., 210, 537  
 Neville Co., 210  
 New Bedford Rayon Co., 379, 388, 388<sub>n</sub>, 547  
 New Bern Cotton Oil & Fertilizer Co., 322<sub>n</sub>  
 New Cornelia Copper Co., 341<sub>n</sub>  
 New England Aniline Works, 233  
 New England Chemical Co., 237  
 New England Gas & Coke Co., 254<sub>n</sub>  
 New England Manufacturing Co., 135<sub>n</sub>, 231<sub>n</sub>  
 New Haven Coke Co., 213  
 New Jersey Alcohol & Chemical Co., 163  
 New Jersey Zinc Co., 368<sub>n</sub>, 369, 370<sub>n</sub>, 374, 382, 437, 513, 524  
 New Kanawha Power Co., 41  
 New Process Corp., 385<sub>n</sub>  
 New York Dock Co., 181<sub>n</sub>

- New York & Pennsylvania Paper Co., 522  
New York Quinine & Chemical Works, 255, 282, 285, 285*n*, 290-91, 299  
New York Sugar Trade Laboratory, 386*n*  
Newark Varnish Works, 211*n*  
Newberry Lumber & Chemical Co., 179*n*  
Newcomer, B. F., 99*n*  
Newhall, T., 289*n*  
\*Newkirk, W. B., 423, 428  
Newman, A. B., 299  
Newman, J. W., 321*n*  
Newport Chemical Co., 108, 300, 302, 344*n*, 356, 357*n*, 538  
Newport Chemical Works, 193, 200  
Newport Co., 23, 94*n*, 253  
Newport Manufacturing Co., 215  
Newton, E. B., 413*n*  
Newton, R. M., 356*n*  
Newton Naval Stores Co., 356*n*  
Niacet Chemicals Corp., 183, 183*n*, 270, 537  
Niagara Alkali Co., 115, 120, 120*n*, 367, 522  
Niagara Ammonia Co., 87-88, 90  
Niagara Falls Power Co., 116*n*  
Niagara Smelting Corp., 202, 202*n*, 522  
Niagara Sprayer & Chemical Co., 341, 345  
Nicholl, L., 156  
Nichols, C. W., 341*n*  
Nichols, W. H., 86, 435  
Nichols Copper Co., 101*n*, 340, 341*n*  
Nicholson, J. G., 57*n*  
\*Nickell, L. F., 39\*, 42, 47, 83  
Niederheim, *see* Chemische Fabrik Niederheim  
Nielsen, C., 255  
Nitardy, F. W., 270  
Nitrate Agencies Co., 335, 338, 345  
Nitrogen Engineering Corp., 87-90, 93, 176, 257  
Nitrogenous & Compositized Fertilizer Co., 58  
Nizer Corp., 425  
Nobel Industries, Ltd., 38, 53, 56, 57*n*, 58*n*  
Nolan, J. I., 220  
Nolte, L., 372*n*  
Norda Essential Oil & Chemical Co., 302  
Norris, G. W., 319, 321-2  
Norris, J. F., 390, 549  
\*North, C. O., 199\*, 224, 414  
North, S., 4*n*  
North American Chemical Co., 130, 130*n*, 143  
North American Molasses Co., 162  
North Butte Mining Co., 341*n*  
North Hudson Chemical Co., 135, 135*n*  
North Shore Coke & Chemical Co., 213  
North Shore Gas Co., 213  
Northern Explosives Co., 137*n*  
Northwestern Chemical Co., 192  
Norton, A. J., 362  
Norton, L. J., 163  
Norton Co., 426*n*, 523  
\*Norvell, S., 279\*, 291  
Norvell Chemical Corp., 253-4, 291  
Norwegian Nitrogen Products Co., 14  
Norwich Chemical Co., 201  
Norwich Pharmacal Co., 303  
Novadel Process Corp., 537  
Novocol Chemical Manufacturing Co., 255, 537  
\*Novotny, E. E., 343\*, 349-50, 544  
Nugent, J. F., 23  
Nutt, L. G., 247, 281-2  
N. V. Potash Export My., 323  
Nyal Co., 239  
Obex Laboratories Co., 538-9  
Oconee Alkali & Chemical Co., 341  
Odell, W. W., 93*n*  
Oenslager, G., 412, 426  
Ogg, W. A., 371*n*  
Ohio Ferro-Alloys Corp., 518  
Ohio River Salt Co., 265  
Ohio Salt Co., 130  
Olcott, H. S., 389  
Old Colony Trust Co., 380*n*  
Old Hickory Chemical Co., 202  
Old Time Molasses Co., 161-2  
Oldbury Electro-Chemical Co., 104, 109, 122*n*, 130-31, 518  
Olive, T. R., 83, 385*n*  
Oliver, T. C., 437  
Oliver Filters Co., 437  
Olney, L. A., 238, 242  
Olsen, J. C., 83, 549  
O'Neil, T., 229  
Orange Grove Refining Co., 164-5, 537  
Orbis Products Trading Co., 298-9  
Orelite Co., 181*n*  
\*Orelup, J. W., 229, 231\*, 233, 241  
Orleans Distilling Co., 165  
Orono Pulp & Paper Co., 420*n*  
Orr, A., 189, 204  
Orr, C. T., 371*n*  
Osborn, H. G., 392*n*, 394, 406  
Osceola Mining Co., 340  
O'Shaughnessy, E. A., 165*n*

\*O'Shaughnessy, V. M., 165, 166\*  
 O'Shea, B., 142*n*, 183  
 Osmun, R. H., 263  
 Ostwald, W., 91-92, 94  
 Otto Chemical Co., 185  
 Owen, E., 406  
 Owenoke Corp., 164*n*  
 Owens, L. C., Jr., 141  
 Owens Bottle Co., 420  
 Owens-Illinois Glass Co., 420  
 Oxford Mining & Milling Co., 421  
 Oxford Packing Co., 328  
 Oxford Paper Co., 522  
 Oxzyn Co., 303  
 Oakland Chemical Co., 137*n*, 138, 524  
 Oakley, R. A., 313*n*  
 Ober, G., Jr., 11, 322*n*, 329  
 Ober & Sons Co., G., 318, 322*n*, 327*n*,  
 329, 519  
 Oberkoks Chemical Co., 38  
 Ozark Chemical Co., 128, 513  
  
 Pacific Alkali Co., 118  
 Pacific Bone Coal & Fertilizing Co., 29  
 Pacific Coast Borax Co., 145, 145*n*,  
 271*n*  
 Pacific Coast Shipbuilding Co., 80  
 Pacific Gas & Electric Co., 80  
 Pacific Guano & Fertilizer Co., 519  
 Pacific Mills, 235*n*  
 Pacific Nitrogen Corp., 88  
 Packard, C. T., 71  
 Paine, H. S., 423  
 Paine, W. S., 213*n*  
 Painter Fertilizer Co., E. O., 512  
 Palatine Aniline & Chemical Co., 237  
 Palmer, A. M., 62, 539  
 Palmer, R. C., 362  
 Palmer Gas Products Corp., 417*n*  
 Palmolive Co., 295, 303  
 Paper Makers' Chemical Co., 420  
 Paper Makers' Chemical Corp., 420  
 Park, J. G., 167, 205  
 Park Co., Phillip R., 424  
 Parke, Davis & Co., 218*n*, 252, 282,  
 282*n*, 289, 436*n*  
 Parker Rust-Proof Co., 108  
 Parmele, C. R., 539  
 \*Parmelee, H. C., 6\*, 10*n*, 11, 435*n*,  
 436*n*, 439, 549  
 \*Parr, S. W., 198\*, 212, 549  
 Parsons, C. L., 92*n*, 93, 95, 539, 549  
 Parsons, L. W., 549  
 Parsons, S. L., 26*n*  
 Parsons & Petit, 197  
 Partridge, E. P., 47, 186, 362, 382*n*  
 Paskus, B. C., 352*n*

Passaic Color Corp., 45, 234  
 Passaic Consolidated Water Co., 523  
 Patart, M., 170-71  
 Patent Chemicals, Inc., 233*n*  
 \*Patrick, J. C., 407\*, 410  
 \*Patrick, W. A., 70, 70*n*, 83  
 Patten, W. D., 103, 124*n*  
 Patterson, A. M., 240, 539  
 Patton, L., 365  
 Patz, E. O., 239  
 Pauly, H., 384*n*  
 Payne, W. D., 224  
 Peabody & Co., Henry W., 268  
 Peacock, J. C., 275  
 \*Pearce, C. S., 295\*, 303  
 Pearce, W. T., 187  
 Pechiney, 58  
 Peek, G. N., 322*n*  
 Peek Chemical Works, 537  
 Peerless Color Co., 229  
 \*Peet, A. W., 295\*, 303  
 Peet Bros., 303  
 Peffer, H. I., 164  
 Peiser, S., 29  
 Pelham Phosphate Co., 512, 519  
 Pelican Gas & Carbon Co., 415*n*  
 Péligot, E., 425*n*  
 Pellens, M., 281*n*  
 Penick & Co., S. P., 303  
 Penick & Ford, 164*n*, 423  
 Penniman, R. S., 372  
 Penning, C. H., 110, 145, 225  
 Pennsylvania Salt Manufacturing Co.,  
 23, 35*n*, 116*n*, 118-9, 124, 131*n*, 135,  
 144, 222, 349, 512-3, 519, 522-3  
 Pennsylvania Salt Manufacturing Co.  
 of Washington, 125*n*  
 Pennsylvania Sugar Co., 162, 166, 425  
 Penobscot Chemical Fibre Co., 522  
 Penrose, B., 8*n*  
 Pepsin Syrup Co., 290  
 Perham Crystal Feldspar Mines, 421  
 Perkin, Sir W., 207, 252*n*  
 Perkins, G. W., Jr., 258  
 Perley, G. A., 92*n*  
 Peroxide Manufacturing Co., 124  
 Perry, R. S., 419, 419*n*  
 Perry Iron Co., 518  
 Perry & Webster, 419  
 \*Peters, C. B., 302, 310\*, 313, 317,  
 317*n*, 329  
 Peters, E. V., 382  
 Peters, F. N., Jr., 361  
 Peters Co., C. B., 317  
 Peters Salt Co., 264  
 Peterson, J. B., 292  
 Petroleum Chemical Corp., 193-4, 537

- Petroleum Products Co., 210<sub>n</sub>  
Pettigrew, H., 129<sub>n</sub>  
Pfaltz, H., 259, 302<sub>n</sub>  
Pfaltz & Bauer, 259  
Pfeiffer, E. J., 264  
Pfeiffer, E. W., 272  
Pfeiffer Chemical Co., 278  
Pfeiffer Color Co., 373  
Pfizer & Co., Chas., 35<sub>n</sub>, 255, 269, 306, 382  
Pfum, J. F., 233  
Pharma-Chemical Corp., 229  
Phelps Dodge Corp., 340, 341<sub>n</sub>  
Philadelphia Quartz Co., 143  
Phulfuels Co., 406  
Phillips, L., 373<sub>n</sub>  
Phillips, M., 201, 225  
Phillips Chemical Co., Chas. H., 247<sub>n</sub>, 290  
Phillips Petroleum Co., 406  
Phosphate Mining Co., 512  
Phosphate Products Corp., 101, 518  
Phosphorus Compounds Co., 104-5, 109  
Phosphorus-Hydrogen Co., 89, 95  
Piccard, J., 433  
Pick Fertilizer Service, 328  
Pickard, F. W., 352<sub>n</sub>  
Pickering & Co., Alexander, 268  
Pickhardt, W. P., 239  
Piedmont Electro Chemical Co., 104  
Piedmont-Mt. Airy Guano Co., 519  
\*Pierce, A. H., 230\*, 230<sub>n</sub>, 235  
Pike, J., 342  
Piron, E., 214  
Pitch Pine Products, Inc., 414  
Pitcher, A. M., 124<sub>n</sub>  
Pitman-Moore & Co., 289  
Pittman, K., 339  
Pittsburgh Coke & Chemical Co., 81  
Pittsburgh Plate Glass Co., 46<sub>n</sub>, 345, 420  
Pittsburgh Provision & Packing Co., 519  
Pittsburgh Safety Glass Co., 420  
Planters' Chemical & Oil Co., 512, 519  
Planters' Fertilizer & Chemical Co., 327<sub>n</sub>, 512  
Planters' Fertilizer & Phosphate Co., 322<sub>n</sub>, 512, 519  
Plaut, E., 277  
Plechner, W. W., 366<sub>n</sub>, 368<sub>n</sub>, 375  
Pocahontas Coal Co., 380<sub>n</sub>  
Poindexter, R. W., 342  
Polack, R. H., 129, 129<sub>n</sub>, 145  
Polk, F. L., 240, 539  
Pollak, B. E., 191  
Pollitt, G. P., 56, 57<sub>n</sub>  
Pomeroy Salt Corp., 265  
Pomilio, U., 433  
Pompeian Manufacturing Co., 303  
Port Morris Chemical Works, 188<sub>n</sub>  
Porter, H. H., 124<sub>n</sub>  
Porter, S., 165  
Porter, S. G., 281-3  
Porter Fertilizer Works, 328, 519  
Portland Gas & Coke Co., 214, 537  
Poss, A., 381  
Poste, E. P., 186  
Postum Co., 425  
Potash Importing Corporation of America, 323  
Potter, E. A., Jr., 124<sub>n</sub>  
Potts Powder Co., 39  
Poucher, M. R., 539  
Poulenc Frères, *see* Etablissements Poulenc Frères  
Pound, J. F., 304  
Powdrell, F. A., 381  
Power, F. B., 288  
Powers-Weightman-Rosengarten Co., 249, 255, 257-8, 282, 285<sub>n</sub>, 437, 512  
Powhatan Fertilizer Co., 519  
Poynton, R. C., 156  
Pratt, J. T., 141  
Pratt, L. A., 83, 95  
Pratt & Lambert, Inc., 357, 365, 373  
Prentiss, M. L., 401  
Prest-Air Devices Co., 426  
Prest-O-Lite Co., 195-7  
Preussische Fiskus, 55<sub>n</sub>  
Priddy & Co., Chas. W., 327<sub>n</sub>  
Prindle, K. E., 352  
Pringle, A. F., 328  
Pringle, E. H., 322<sub>n</sub>  
Pritchard, D. A., 112<sub>n</sub>, 119<sub>n</sub>  
Producers Oil Co., 74  
Provident Chemical Works, 103-4, 518  
Prudential Life Insurance Co., 380<sub>n</sub>  
Pryor, S. F., 164<sub>n</sub>  
Public Service Corp., 212  
Publicker, H., 162  
Publicker, P., 162, 165, 181<sub>n</sub>  
Publicker, Inc., 192, 537  
Publicker Commercial Alcohol Co., 162, 166, 181, 189<sub>n</sub>  
Pulaski Iron Co., 518  
Pure Carbonic Company of America, 164  
Pure Oil Co., 193, 394  
Puritan Chemical Co., 344<sub>n</sub>  
\*Putnam, M. E., 198\*, 535  
Pyridium Corp., 290  
Pyrites Co., Ltd., 82-83, 370  
Pyroxylin Products Co., 359, 544

- Quaker Oats Co., 350, 544-5  
 \*Queeney, E. M., 39\*, 43  
 Queeney, J. F., 42-43, 217*n*  
 Quinn, J., 129*n*  
 Quinn, J. F., 237  
 Quinn, J. G., 237  
 Quinn, M. F., 172*n*, 173, 180, 182*n*, 185  
 Quinn, M. M., 182*n*  
 Quinn, M. T., 237  
 Quinn, R. J., 27, 95, 427  
 Quinn, T., 173*n*  
 Quinton Spelter Co., 371*n*  
  
 Rabinovitz, L., 361  
 Rademaker, J. H., 264  
 Rademaker Chemical Co., 264  
 \*Rafferty, J. A., 61*n*, 182\*, 183, 196, 549  
 Raines, W. H., 364*n*  
 Raisin Monumental Co., 512  
 Raiziss, G. W., 249*n*, 251  
 Ralli, V. P., 156  
 Ralston, O. C., 375  
 Ramirez, P., 314  
 Ramsburg, C. J., 224, 313, 434  
 Ramsey, J., 83  
 Rand, W. M., 20*n*, 21*n*, 42  
 Ransom, A. C., 415  
 Rare Chemicals, Inc., 290  
 Raritan Aniline Works, 401  
 Raskob, J. J., 38*n*  
 Razor, C. M., 145, 271*n*  
 Rassieur, T., 280  
 Rathbone & Son, R. C., 181*n*  
 Rathoon, N. P., 191*n*  
 Rau, B., 237  
 Rauh & Sons Fertilizer Co., E., 322*n*, 237*n*, 519  
 Raven Carbon Co., 415*n*  
 Read, A. C., 328-9  
 Read, B. E., 540  
 Read, W. T., 438  
 Read Fertilizer Co., 512  
 Read, Holliday & Sons, Ltd., 57  
 Read, Holliday & Sons Co., 236  
 Read Phosphate Co., 327*n*, 328-9, 512, 519  
 Reading, Marquis of, 57*n*  
 Reading Bone Fertilizer Co., 519  
 Reagan, D. J., 12*n*, 13*n*, 63  
 Real Silk Hosiery Mills, 211*n*  
 Redd Chemical & Nitrate Co., 519  
 Redman, L. V., 216, 349*n*, 436, 549  
 Redmanol Chemical Products Co., 349*n*  
 Redwood, B., 393*n*  
 Reed, C., 26*n*  
 Reed, C. H., 361  
 Reed, L. C., 343*n*  
 Reed & Carnrick, 253*n*  
 Reedy Power Co., 320  
 Reese, C. L., 10*n*, 60*n*, 61, 163*n*, 154, 403*n*, 433, 437, 549  
 Refiners Oil Co., 401  
 Regnier & Son Co., John, 420*n*  
 Reich, G. T., 426  
 \*Reichel, F. H., 343\*, 353  
 Reichert, J. S., 427  
 Reichert, T., 179*n*  
 Reichhold, H. H., 359  
 Reichhold Chemicals, Inc., 359  
 Reid, E. W., 204  
 Reid, H. S., 183  
 \*Reilly, P. C., 199\*, 211  
 Reilly Chemical Co., 211  
 Reliance Coke & Furnace Co., 518  
 Reliance Fertilizer Co., 327*n*, 512, 519  
 Remfry, F. G. P., 146  
 Remington-Rand, Inc., 134*n*  
 Remsen, I., 250  
 Renshaw, R. R., 252  
 \*Rentschler, M. J., 134\*, 137  
 Republic Creosoting Co., 211  
 Republic Mining & Manufacturing Co., 132*n*, 523  
 Republic Rubber Co., 224*n*, 411*n*, 414  
 Resinous Products & Chemical Co., 166*n*, 354, 357-9  
 Resor, R. P., 396*n*  
 Reynolds Chemical Corp., 537  
 Rheinisch - Westfälische Sprengstoff A.-G., 53  
 Rheinische Kampfer u. Celluloid Fabrik, 300*n*  
 Rhenania Kunheim Verein Chemischer Fabriken, 138  
 Rhodes, E. O., 210*n*, 427  
 Rhodia Chemical Co., 108, 253, 298, 302, 383  
 Rianhard, T. M., 549  
 Richards, F. R. G., 108  
 Richards, J. W., 126  
 Richards, L., 189*n*  
 Richardson, C. H., 346  
 Richardson, C. N., 87*n*, 110  
 Richardson, C. W., 282  
 Richardson, R. S., 92*n*  
 Richardson, T., 264  
 Richardson, W. D., 549  
 Riches, Piver & Co., 336*n*  
 Richmond, G. F., 550  
 Richmond Guano Co., 328, 512, 519  
 Richter, G. A., 386, 389  
 Rickenbach, W. H., 197*n*, 205

- Riddle, E. H., 428  
 Rideal, B. K., 433  
 Riebeck'sche Montanwerke A.-G., A., 53  
 Riedel-E. de Haën A.-G., J. D., 166*n*, 259  
 Riedemann, H. A., 396*n*  
 Riegel, E. R., 83  
 Riggs, L. K., 269, 273, 288, 424  
 Rigney, P. S., 23, 26, 60*n*, 153*n*, 183, 239, 503-4, 549  
 Riker, C. L., 116  
 Riker, D. S., 116  
 Riker, J. L., 116  
 Riker, J. L. & D. S., 115-6  
 Riley, J. J., 137, 195  
 Rio Tinto Co., Ltd., 82-83, 101*n*, 328  
 Riordan Pulp Corp., Joseph, 119  
 Ripans Chemical Co., 290  
 Rippingille, E. V., 260*n*, 397*n*  
 Rittman, W. F., 393  
 \*Rivitz, H. S., 375\*, 379, 388  
 Roanoke Guano Co., 512, 519  
 \*Roark, R. C., 326\*, 333, 343, 346-7  
 Robbins, H. D., 291  
 Roberts, T., 229  
 Robertson, G. R., 147  
 Robertson, H. F., 205  
 Robertson Chemical Corp., 512, 519  
 Robertson Products Co., 344*n*  
 Robins, E. L., 322*n*, 329  
 Robins, G. S., 117*n*  
 Robins & Co., G. S., 117  
 Robinson, A. G., 431*n*  
 Robinson, E. G., 550  
 Robinson Bros. Co., 512  
 Rochester Germicide Co., 344*n*  
 Rockefeller, J. D., 390  
 Rockefeller, P. A., 164, 380*n*  
 Rockhill & Victor, 303-4  
 Rodius-Koenigs Trading Corp., 380*n*  
 Roessler & Hasslacher Chemical Co., 23, 28, 88, 119, 162, 176*n*, 183, 199, 203, 215, 270, 362*n*, 411, 421, 425, 437  
 Rogers, A., 431*n*  
 Rogers, F. A., 163, 165  
 Rohm & Haas Co., 339, 343, 354, 357, 359  
 Roka, K., 184*n*  
 Roll, G. H., 550  
 Rollin Chemical Co., 136, 194-5  
 Romaine, E. V., 362  
 Rommel, G. M., 387  
 Ronalds, T., 365*n*  
 Roop, M. C., 83-84  
 Roosevelt, T., 50  
 Root, E., 161*n*  
 Rosenberg, S. M., 344*n*  
 Rosengarten, A. G., 256, 258, 437, 549  
 \*Rosengarten, F., 11, 258, 263\*  
 Rosengarten, G. D., 258, 433*n*, 549  
 Rosengarten, J. G., 258  
 Rodier, J. H. D., 23, 504  
 Rosland Corp., 385, 547*n*  
 Ross, W. H., 104, 106*n*  
 Rossman, J., 361  
 Rossville Commercial Alcohol Corp., 164, 164*n*, 191  
 Rossville Co., 162, 164-5  
 Rowland, R. B., Jr., 328  
 Rowlands, L., 366  
 Royal Baking Powder Co., 103, 424  
 Royal Dutch Petroleum Co., 89  
 Royal Dutch Shell Oil Co., 395  
 Royster Guano Co., F. S., 87, 322*n*, 327*n*, 512, 519  
 Rubber Regenerating Co., 414  
 Rubber Service Laboratories Co., 42, 224, 270, 414, 537  
 Rubens, H., 161  
 Ruckgaber P., 189*n*  
 Rue, J. D., 427  
 Ruggles, C. H., 264  
 Ruggles & Rademaker, 264  
 Rumford Chemical Works, 103, 423, 518  
 \*Russe, F. W., 259, 262\*, 270, 273, 287  
 Russell, G. A., 296, 298  
 Russell, H. E., 109  
 \*Russell, R. P., 390\*, 396, 405  
 Russell, W., 83  
 Ryan, A. A., 253  
 Ryan, L. W., 366*n*  
 Ryan, W. J., Jr., 405*n*  
 Rykenboer, E. A., 91*n*  
 Sabatier, P., 170-71  
 Sachs, A. P., 241, 549  
 Sagarin, F., 297*n*, 306  
 Saginaw Salt Products Co., 265  
 Sailer, W. A., 154  
 St. Bernard Acid Works, 512  
 St. Gobain, 58  
 St. John, A., 433  
 St. Joseph Lead Co., 369, 371-2  
 St. Louis Gas & Coke Corp., 518  
 Saklatwalla, B. D., 47, 83  
 Saline Products Co., 265  
 Salt Lake Insecticide Co., 335-6  
 \*Salvage, Sir S. A., 374\*, 388  
 Salzbergwerk Neustassfurt, 59  
 Salzdetfurth A.-G., 55*n*, 324*n*  
 Sand Springs Chemical Co., 265

- Sandee Co., 289  
 Sanderson & Porter, 124*n*  
 Sandles, A. P., 321*n*  
 Sandoz Co., 236  
 Sanford, J. E., 322*n*  
 Sanitol Chemical Laboratory Co., 290  
 Sargent, J. G., 241  
 Saunders, C. A., 174*n*, 180, 185  
 Saunders, W. L., 172*n*, 173, 180  
 Savannah Guano Co., 512  
 \*Savell, W. L., 134, 135\*, 146, 219  
 Savell, Sayre & Co., 134, 537  
 Sawyer, A. W., 417  
 Sawyer, H. P., 266, 272  
 Sayers, R. R., 403, 407  
 Schaal, E., 355*n*  
 Schaefer, A. E., 264*n*  
 Schaeffer, J. A., 371  
 Schaetzer, C., 302*n*  
 Schantz, J. L., 362  
 Schedler, C. W., 89  
 Scheffer, W. B., 338  
 Schenk, P. D., 437  
 Schering Corp., 302  
 Schering-Kahlbaum A.-G., 302  
 Schidrowitz, P., 412*n*  
 Schieffelin, W. J., 154  
 Schimmel & Co., 297*n*, 299  
 Schleusner, P., 26*n*, 183, 346, 549  
 Schmidel, T., 71  
 Schmidt, C. F., 283-4, 540  
 Schmidtmann, W., 323  
 Schmits, H. W., 539  
 Schmitz, H., 236*n*  
 Schneider, C., 171*n*  
 Schneider-Creuzot, 395  
 Schnell, H. J., 155*n*, 344, 437  
 \*Schoch, E. P., 311\*, 326, 331  
 Schoellkopf, J. F., Jr., 417  
 Scholl, W., 205  
 Schorger, A. W., 201*n*  
 Schreiber, W. T., 428  
 Schrenk, O. von, 396*n*  
 Schroeder, J. E., 74  
 Schroeder, M., 70  
 Schroeder, W. F., 145  
 Schulman, S., 302*n*  
 Schulte, D. A., 303  
 Schultz, A., 33  
 Schulze, T., 191*n*  
 Schumann, J. H., 360  
 Schuster, J. F., 205  
 Schwarz, R., 436  
 Scott, C. N., 74  
 Scott, R. W., 381  
 Scott, T. J., 223*n*  
 Scott, W., 411, 414  
 Scott Hosiery Mills, R. W., 381  
 Scott & Turner, Ltd., 290  
 Scottish Agricultural Industries, Ltd., 58  
 Scottish Dyes, Ltd., 57  
 Scull, F. R., 383  
 Seaboard By-Product Coke Co., 80  
 Seaboard Chemical Co., 164  
 Seaboard Railroad, 329*n*  
 Seagram & Sons, Jos. E., 164*n*  
 Searle & Co., G. D., 259  
 Searle & Hereth, 278  
 \*Seaton, M. Y., 263\*, 265, 272  
 Seeley, M., 302  
 Seeley & Co., 302  
 Seely, F. L., 380*n*  
 Sefström, N. G., 41*n*  
 Seiberling, F. A., 224  
 Seidel, H. G., 396*n*  
 Seidell, L. R., 549  
 Seladeux, 106  
 \*Selden, J. M., 214\*, 219*n*  
 Selden, J. M., Jr., 219*n*  
 Selden Co., 44-46, 69-70, 83, 219-20, 257, 510-11  
 Self, S. B., 205  
 Selig Co., 344*n*  
 Sellards, E. H., 326  
 Seltmann, W. A., 302*n*  
 Semet-Solvay Co., 90*n*, 93, 123, 130, 143, 210, 212-4  
 Semet-Solvay Engineering Corp., 210  
 \*Semon, W. L., 407\*, 413, 427  
 Seydel, H., 200*n*  
 Seydel Chemical Co., 255  
 Seyfried, W. R., 107  
 Sharon Steel Hoop Co., 72  
 Sharp & Dohme, Inc., 154, 218*n*, 232*n*, 245, 251, 289  
 Sharpell, A. C., Jr., 191*n*  
 \*Sharples, P. T., 183\*, 191, 404  
 Sharples Separator Co., 191*n*  
 Sharples Solvents Corp., 192, 192*n*, 199, 391, 405, 537  
 Sharples Specialty Co., 191-2  
 Shaw, E. P., 324  
 Shawinigan Products Corp., 182, 200  
 Shawinigan Water & Power Co., 182, 182*n*  
 \*Sheldrick, R., 7\*, 26*n*  
 Shell Chemical Co., 89  
 Shell Development Co., 89  
 Shell Oil Co., 219*n*, 392*n*  
 Shell Union Oil Corp., 89  
 Shenango Furnace Co., 518  
 Shepard, H. H., 346  
 Shepard, N. A., 427



- Sheppard, M., 325  
 Sheppard, S. E., 413  
 Sherman & Sterling, 164*n*  
 Sherndal, A. E., 292  
 Sherwin-Williams Co., 233*n*, 234*n*, 335*n*,  
 338, 345, 354, 361, 369, 524  
 Shirley, J. N., 213*n*  
 Shoeld, M., 318*n*  
 Shoemaker & Co., Robert, 291  
 Shreve, R. N., 238  
 Shreveport Fertilizer Works, 519  
 Shutt, F. T., 272  
 Sibley, R. L., 427  
 Sidebottom, H. G., 211*n*, 431*n*  
 Siegle Corporation of America, G., 373  
 Sierra Magnesite Co., 139, 265  
 Signer, F. E., 549  
 Silica Gel Corp., 70, 70*n*  
 Silica Gel, Ltd., 70*n*  
 Sill, T. W., 27, 550  
 Silverman, A., 420, 427  
 Simms, E. F., 77  
 Simon, C., 282*n*  
 Simon, C. K., 436, 549  
 \*Simon, G. W., 246\*, 254  
 Simons, Inc., Harold L., 537  
 Simpkins, H. W., 259  
 Sinclair Refining Co., 393  
 \*Singmaster, J. A., 358\*, 369  
 Singmaster & Breyer, 369*n*  
 Skelly, J. T., 12  
 Skenandoa Cotton Co., 379  
 Skenandoa Rayon Corp., 379, 388*n*, 547  
 Skinner, H. J., 361, 427  
 Skinner, W. W., 279  
 Skowronski, S., 549  
 Slama, F., 68-69, 510-11  
 Slate, T. B., 426  
 Slaughter, B. G., 388  
 Slemp, C. B., 321*n*  
 Sloan, A. P., Jr., 38*n*, 57, 401-2  
 Sloan, F. H., 304  
 Sloan, R. R., 304  
 Sloss, 338  
 Sloss-Sheffield Steel & Iron Co., 518  
 Small, E. J., Jr., 224  
 Smeaton, J. V., 300  
 Smith, A. H., 77  
 Smith, A. Homer, 153, 289  
 Smith, A. V., 13*n*  
 Smith, A. W., 549  
 Smith, B. O., 142*n*  
 Smith, C. C., 323*n*  
 Smith, C. R., 346  
 Smith, E. E., 145  
 Smith, E. F., 435*n*  
 Smith, G. O., 325*n*  
 Smith, H. E., 291*n*  
 Smith, J. C., 183  
 Smith, J. T., 402  
 Smith, L. H., 321*n*  
 Smith, L. T., 221  
 Smith, N. L., 416*n*  
 Smith, O. F., 328, 331  
 Smith, W., 358, 362  
 Smith, W. N., 128  
 Smith, W. V., 291*n*  
 Smith Agricultural Chemical Co., 327*n*,  
 512, 519  
 Smith & Co., Valentine H., 291  
 Smith, Kline & French Co., 291, 303  
 Smith, Kline & French Laboratories,  
 291  
 Smith-Rowland Co., 328  
 Smoot, A. M., 436  
 Smootz, J. P., 397*n*, 398  
 Snell, F. D., 389  
 Snell, R. M., 419*n*  
 Snia Viscosa, 379, 379*n*, 417  
 Snider, C. A., 78  
 Snowden & McSweeney Co., 326  
 Snyder, C. U., 163  
 Snyder, F. D., 87  
 Snyder, J. L. K., 203  
 Snyder Co., C. U., 163  
 Société Chimique des Usines du Rhône,  
 302, 383  
 Société Commerciale des Potasses d'Al-  
 sace, 323  
 Société Industrielle du Titane, 367  
 Société des Phosphates Tunisiens, 106  
 Société des Produits Chimiques des  
 Terres Rares, 368  
 Société Rhodiaceta, 383  
 Société Ricard, Allenet & Cie, 166  
 Société des Usines Chimiques Rhône-  
 Poulenc, 253  
 Soda & Potash Corp., 324  
 Sodium Products Corp., 129  
 Soelle, J. C., 191*n*  
 Solid Carbonic Co., Ltd., 426  
 Solid Dioxide Corp., 426  
 Solvay et Cie, 58  
 Solvay Process Co., 29, 93, 113, 115,  
 117, 119, 120*n*, 123, 130, 143, 210,  
 521-2, 537  
 Solvay Sales Corp., 123  
 Somers, F. A., 80  
 Somerset Aniline Works, 537  
 Soper, M. A., 327  
 Sorin & Cie, A., 253  
 South Penn Oil Co., 195  
 Southern Acid & Sulphur Co., 129*n*,  
 512-3

- Southern Agriculture Chemical Corp., 519  
 Southern Alkali & Chemical Co., 341  
 Southern Aromatics Co., 537  
 Southern Bauxite Co., 132<sub>n</sub>  
 Southern California Edison Co., 193<sub>n</sub>  
 Southern Carbon Co., 415  
 Southern Chemical Co., 128  
 Southern Dyestuff Corp., 232  
 Southern Dyestuffs Co., 224, 232<sub>n</sub>  
 Southern Fertilizer & Chemical Co., 322<sub>n</sub>, 327<sub>n</sub>, 512, 519  
 Southern Manganese Corp., 106<sub>n</sub>, 518  
 Southern Phosphate Corp., 98-99  
 Southern Power Co., 193<sub>n</sub>  
 Southern States Phosphate & Fertilizer Co., 512, 519  
 Southern Sulphur Oil Co., 512  
 Southern Sulphur Ore Co., 512  
 Spangler, S. F., 83  
 Spanish Bank of Havana, 372<sub>n</sub>  
 Sparre, F., 352<sub>n</sub>  
 Spaulding & Bros., A. G., 412  
 Speh, C. F., 356<sub>n</sub>  
 Speiden, E. C., 119, 125, 222<sub>n</sub>  
 Spencer-Kellogg Co., 374  
 Sperr, F. W., Jr., 81<sub>n</sub>, 84  
 Spitz, S. J., 357<sub>n</sub>  
 Sponsler, A. L., 321<sub>n</sub>  
 Springorum, W., 380<sub>n</sub>  
 \*Spruance, W. C., Jr., 342\*, 352<sub>n</sub>  
 Spruth, H. C., 256  
 Squibb & Sons, E. R., 218<sub>n</sub>, 248-9, 270, 276, 289, 424<sub>n</sub>  
 Squibb & Sons of Canada, Ltd., E. R., 289  
 Squibb & Sons Inter-American Corp., E. R., 270<sub>n</sub>  
 Staber, H. T., 232<sub>n</sub>  
 Stafford, O. F., 179  
 Staiti, H. T., 76<sub>n</sub>  
 Staley Manufacturing Co., A. E., 423  
 Stallman, A. C., 304  
 Stallman, F. L., 304  
 Stallman, J. H., 304  
 Stallman & Fulton, 304  
 Stamp, Sir J., 57<sub>n</sub>  
 Standard Acid Works, 70, 72  
 Standard Alcohol Co., 165<sub>n</sub>, 194  
 Standard Brands, Inc., 424  
 Standard Carbon Co., 415<sub>n</sub>  
 Standard Chemical Co., 41, 301<sub>n</sub>, 512, 519  
 Standard Fertilizer Co., 328, 519  
 Standard-I.G. Co., 396  
 Standard Oil Co., 171<sub>n</sub>, 175, 201, 394  
 Standard Oil Co. (Calif.), 405  
 Standard Oil Co. (Ind.), 187<sub>n</sub>, 392, 393<sub>n</sub>, 401, 401<sub>n</sub>  
 Standard Oil Co. (La.), 396, 396<sub>n</sub>, 416<sub>n</sub>  
 Standard Oil Co. (N. J.), 12, 36, 189<sub>n</sub>, 193-4, 236, 261, 343, 392<sub>n</sub>, 393, 395, 396<sub>n</sub>, 401<sub>n</sub>, 402, 403<sub>n</sub>, 405, 512  
 Standard Oil Development Co., 80, 193<sub>n</sub>, 199, 394-6, 396<sub>n</sub>, 397<sub>n</sub>, 401, 405  
 Standard Potash Corp., 325  
 Standard Ultramarine Co., 237, 537  
 Standard Varnish Works, 360  
 Standard Wholesale Phosphate & Acid Works, 510, 512-3, 519  
 Standard Wholesale Phosphate Co., 72  
 Stange Co., Wm. J., 537  
 Stanley, A. O., 11  
 Stanley, W. W., 346  
 Starkweather & Williams, Inc., 155<sub>n</sub>  
 States Metals Co., 410<sub>n</sub>  
 Stauffen, E., 289<sub>n</sub>  
 Stauffen, E., Jr., 289<sub>n</sub>  
 Stauffer, H., 359  
 \*Stauffer, J., 29, 38\*, 202  
 Stauffer, J., Jr., 359  
 Stauffer Chemical Co., 29, 82, 181, 202, 265, 360, 512-3, 523  
 Stearns, F. K., 434  
 Stearns & Co., F., 218<sub>n</sub>, 276, 285<sub>n</sub>, 289, 434  
 Stecher, F. W., 303  
 Steel Cities Chemical Co., 512  
 Steele, B. P., 116<sub>n</sub>  
 Steere Engineering Co., 210  
 Steinschneider, W., 232<sub>n</sub>  
 Stenhouse, 342<sub>n</sub>  
 Sterling, J. W., 434  
 Sterling, M., 291  
 Sterling Products Co., 247-8, 290  
 \*Steudel, A. W., 358\*, 361, 368  
 Stevens, E. B., 174<sub>n</sub>  
 Stevenson, Sir J., 409  
 Stewart, L. C., 272  
 Stickstoff Syndikat, 313, 317  
 Stieglitz, J., 403<sub>n</sub>, 432, 539  
 Stiles, J. F., Jr., 539  
 Still, T. W., 539  
 \*Stilling, S. H., 167\*, 172, 174  
 Stillwell, A. G., 436  
 \*Stine, C. M. A., 205, 228, 230\*, 272, 399, 433<sub>n</sub>  
 Stinnes, H., 395  
 Stinnes-Rhein-Elbe-Schuckert-Union, 395  
 \*Stocking, G. W., 54, 311\*, 324, 330-31  
 Stockton, P., 380<sub>n</sub>  
 Stoddard, R. B., 296

\*Stokes, J. S., 343\*, 349, 544  
 Stokes & Smith Co., 349, 537, 544  
 Stone, H. F., 241  
 Stone, R. W., 146  
 Storch, H. H., 176*n*, 325, 331, 395*n*  
 Storck, G. W., 539  
 Stout, G. D., 258*n*  
 Stovall, F., 415*n*  
 Straw, S. A., 396*n*  
 Strecker, C. F., 539  
 Strobhar, A. D., 322*n*  
 Strosacker, C. J., 270  
 \*Stull, P. B. (Hercules Powder Co.), 375\*  
 Suida, H., 184  
 Sulexco (Sulphur Export Corp.), 78-79  
 Sulfat-Vereinigung, 129  
 Sullivan & Cromwell, 258, 329  
 Sulphur Export Corp. (Sulexco), 78-79  
 Sulzberger, F. L., 373*n*  
 Summers, F. P., 550  
 Summers Fertilizer Co., 327*n*, 519  
 Sun Color & Chemical Co., 373  
 Sun Oil Co., 211*n*  
 Sunbeam Chemical Co., 233*n*  
 Superior Bauxite Co., 132*n*, 523  
 Superior Chemical Co., 45, 102, 523  
 Superior Pine Products Co., 420*n*  
 Superior Sizing Co., 420*n*  
 Superior Steel & Malleable Castings Co., 518  
 Superior Zinc Corp., 370  
 Suter, C. M., 195  
 Sutton Chemical Co., 181  
 Swain, C. O., 402  
 \*Swan, C. A., 294\*, 302  
 Swann, T., 103-6, 110, 222  
 Swann & Co., 104*n*  
 Swann Corp., 104*n*  
 Swann-Myers Co., 289  
 Sweatt, H. B., 361  
 Swedish Wargons Co., 318  
 Swenarton, W. H., 539  
 Swenson, E. P., 75  
 Swenson, S. M., 79  
 Swift, A. H., 429*n*, 440  
 Swift & Co., 519  
 Swift Fertilizer Co., 327*n*, 512  
 Switz, T. M., 47  
 Sylvania Industrial Corp., 353  
 Sylvester, J. C., 189*n*  
 Syncho Products Corp., 300  
 Synfleur Scientific Laboratories, 298  
 Synthe-Copal Co., 359  
 Synthetic Ammonia & Nitrates, Ltd., 56  
 Synthetic Iron Color Co., 372

Synthetic Nitrogen Products Corp., 313, 317, 317*n*  
 Synthetic Products Co., Ltd., 190  
 Syrup Products Co., 162  
 Szamatolski, M., 301  
  
 Tacoma Electrochemical Co., 125  
 Tainton, U. C., 370  
 Taiwan Camphor Producing Co., 300  
 Takamine Laboratory, 11*n*  
 Talbot, F., 225, 306, 426  
 Talbot, H. P., 549  
 Talladega Fertilizer Manufacturing Co., 519  
 Tampico Gas Co., 415*n*  
 Tanham, M. E., 381*n*  
 Tanner, W. L., 549  
 Tanner Kelp Products Co., 424  
 Tapley, M. W., 270  
 Tarapaca & Tocopilla Nitrate Co., 316  
 Taussig, F. W., 297  
 Taylor, C. A., 205  
 Taylor, C. M., 192  
 \*Taylor, E. A., 119\*, 123  
 Taylor, E. C., 63  
 Taylor, E. M., 117  
 Taylor, E. R., 202  
 Taylor, G. B., 83, 95  
 Taylor, G. E., 44  
 Taylor, H., 390  
 Taylor, H. S., 205  
 Taylor, R. L., 153*n*, 381*n*  
 Taylor, T. J., 356*n*  
 Taylor Chemical Co., 202-3  
 Taylor, Ewart & Co., 124*n*  
 Taylor, Lowenstein & Co., 356*n*  
 Teagle, W. C., 12, 236, 390, 395, 402  
 Technic, Inc., 231*n*  
 Technical Economists, Inc., 232  
 Teeple, J. E., 228, 324, 324*n*, 330, 433, 433*n*, 439, 549  
 Tees Salt Co., Ltd., 57  
 Teeter, A. A., 273  
 Tegner, H. S., 397*n*, 406  
 Tennessee Chemical Co., 68*n*, 512, 519  
 Tennessee Copper & Chemical Corp., 81, 512  
 Tennessee Copper Co., 71*n*  
 Tennessee Eastman Corp., 174, 178-80, 351, 360*n*  
 Tennessee Electric Power Co., 319  
 Tennessee Mineral Products Corp., 421  
 Tennessee Products Corp., 178, 180, 518  
 Terry, C. E., 281*n*  
 Terry, E., 4  
 Texaco Salt Products Co., 265

- Texas Carbon Industries, Inc., 416  
 Texas Chemical Co., 29, 513  
 Texas Co., 74-75, 132*n*, 265, 394, 404, 405*n*  
 Texas Exploration Co., 74  
 Texas Gulf Sulphur Co., 73, 75, 77-78, 79*n*  
 Textile Chemical Co., 45*n*, 231-2  
 Thacher, C. J., 223*n*  
 Thayer, F. K., 251  
 Theil, S. S., 253  
 Theratomic Carbon Co., 189*n*  
 Thermo Chemical Co., 299*n*  
 Thilmany Pulp & Paper Co., 419*n*  
 Thiokol Corp., 410  
 Thole, F. B., 146  
 \*Thom, W. B., 26*n*, 119\*, 123-4, 196  
 Thomas, A. W. S., 436  
 Thomas, S., 4*n*  
 Thomas Co., N. Spencer, 237*n*  
 Thomas & Son, I. P., 322*n*, 327*n*, 512, 519  
 Thompson, C. T., 25*n*, 117*n*  
 Thompson, E. C., 146  
 Thompson, G., 403*n*  
 Thompson, H., 23  
 Thompson, H. B., 280, 539  
 \*Thompson, H. E., 182\*, 196  
 Thompson, J., 306  
 Thompson, W. B., 78*n*  
 Thompson - Hayward Chemical Co., 117*n*  
 Thompson - Munro - Robins Chemical Co., 117*n*  
 Thompson, Weinman & Co., 524  
 \*Thomson, S. H., 103, 118\*  
 Thomson, W. H. S., 69  
 Thomssen, E. G., 306  
 Thornley & Co., 424  
 Thorp, W. L., 46*n*, 47  
 Three-in-One Oil Co., 290  
 Tide Water Associated Oil Co., 405  
 Tide Water Oil Co., 188*n*, 404  
 Tierney, J. I., 10*n*, 60*n*, 549  
 \*Tilden, P. S., 7\*, 23, 504  
 Tinc Tura Laboratory, 240*n*  
 Titan Co., A/S, 367  
 Titanium Alloy Manufacturing Co., 421  
 Titanium Pigment Co., 137, 367, 524  
 Toch Bros., 360  
 Todhunter, B. E., 57*n*  
 Toledo Furnace Co., 518  
 Toulon Arsenic Co., 334  
 Tour, R. S., 86*n*  
 Tower Manufacturing Co., 229, 233, 239*n*  
 Townend, D., 123  
 Townsend, C. P., 125  
 Travancore Minerals Co., 368  
 Treadgold, A. G., 427  
 Treadwell, J. B., 268  
 Treyz, G. H., 182*n*  
 Treyz, G. I., 182*n*  
 Trickey, J. P., 361, 544  
 Trico Chemical Co., 45*n*  
 \*Trigg, E. T., 11, 327\*, 344  
 Triplex Safety Glass Company of North America, 420  
 Trojan Powder Co., 513  
 Troostwyk, 199*n*  
 Tropsch, H., 433  
 Trout Co., 512  
 Trowbridge, M., 27  
 Troy, J., 182*n*, 185  
 Trubek, M., 166  
 Trubek, R., 297*n*  
 Trumbull, H. L., 411  
 Trusler, R. B., 428  
 Tubize Artificial Silk Company of America, Inc., 87, 137, 378-9, 381-2, 384, 388, 388*n*, 547  
 Tubize Chatillon Corp., 384*n*  
 Tuckwood, O. W., 28  
 Tufts, W. E., 439  
 Tumpeer, D., 416  
 Tunison, B. R., 26, 26*n*, 27, 151, 164, 186, 204, 550  
 Tunnell & Co., F. W., 327*n*, 512, 519  
 Tupelo Agricultural Chemical Co., 512  
 \*Turner, C. N., 6\*, 10*n*, 23, 504, 550  
 \*Turner, J., 26*n*, 116-7, 119  
 Turner, M. E., 137  
 Turner, W. H., 70*n*  
 Turner & Co., J., 117  
 Turrentine, J. W., 272, 325*n*, 330, 433*n*  
 Tuttle, W. F., 439  
 Twombly, W. F., 416, 427  
 Tyler, P. M., 145  
 Tyler, D., 215  
 Udden, J. A., 325  
 Udy, M. J., 142  
 Ufficio per la Vendita dello Zolfo Italiano, 79*n*  
 Uhlich & Co., Paul, 373  
 Ultro Chemical Corp., 232, 373  
 Ungerer, F. H., 304  
 Ungerer, W. G., 304, 307  
 Ungerer, W. P., 304  
 Ungerer & Co., 296, 303*n*, 304  
 Ungerleider, S., 379  
 Ungewitter, C., 17, 18*n*, 60-61  
 Union Acid Co., 57

- Union Carbide and Carbon Corp., 11,  
 11*n*, 33, 40-42, 141, 142*n*, 171*n*, 175,  
 182-3, 183*n*, 195-6, 199*n*, 318-21  
 Union Carbide and Carbon Research  
 Laboratories, Inc., 142, 194  
 Union Charcoal & Chemical Co., 185  
 Union Seed & Fertilizer Co., 512  
 Union Solvents Corp., 191  
 Union Sulphur Co., 73-79, 83  
 Union Trust Co., 211*n*, 380*n*  
 Unione Italiana Fabbrica Viscosa, 379*n*  
 United Alkali Co., Ltd., 55, 55*n*, 56, 57*n*  
 United Carbon Co., 415, 415*n*, 416*n*,  
 417*n*  
 United Chemical Co., 328, 512  
 United Chemicals, Inc., 124, 136, 424  
 United Chromium, Inc., 142  
 United Color & Pigment Co., 253*n*,  
 369, 372, 524  
 United Copper, Co., 341*n*  
 United Drug Co., 276  
 United Feldspar Corp., 421  
 United Gas Corp., 77*n*  
 United Gas Improvement Co., 512  
 United Lead Co., 367  
 United Molasses Co., Ltd., 162  
 United Oil & Natural Gas Products  
 Corp., 415*n*  
 United Piece Dye Works, 301*n*  
 United Shoe Machinery Co., 353  
 United States Feldspar Corp., 421  
 United States Finishing Co., 539  
 U. S. Food Products Corp., 189  
 U. S. Industrial Alcohol Co., 23, 27-28,  
 155*n*, 161-4, 166, 175, 181*n*, 200*n*,  
 204, 323, 368, 433  
 U. S. Industrial Chemical Co., 154,  
 166, 190, 192, 200, 204, 298, 324  
 U. S. Phosphoric Products Corp., 71*n*,  
 519  
 United States Potash Co., 326, 331  
 United States Rubber Co., 97*n*, 412-3  
 U. S. Sanitary Specialties Corp., 333*n*  
 U. S. Smelting, Refining & Mining Co.,  
 271, 334, 337  
 United States Steel Corp., 36, 38, 209,  
 213, 506  
 United States Vanadium Co., 41  
 United States Vanadium Corp., 41*n*  
 United Verde Copper Co., 341*n*  
 United Zinc Smelting Corp., 371*n*, 512  
 Universal Oil Products Co., 390, 393  
 Upjohn Co., 218*n*, 252  
 Upton-Kelley Co., 128*n*  
 Utah Copper Co., 340, 341*n*  
 Vacuum Can Co., 141-2  
 Vacuum Oil Co., 320*n*  
 Vail, J. G., 146  
 Vail, W. E., 194  
 Valentine & Co., 187  
 \*Van Ameringen, A. L., 294\*, 302  
 Van Ameringen-Haebler, Inc., 192,  
 302, 537  
 Van Bemmelen, J. M., 358*n*  
 Van Berlo, E., 26*n*  
 Van Camp Packing Co., 422  
 Van Doren, L., 436, 549  
 Van Dyk, L. A., 302  
 Van Dyk & Co., 296-7, 302*n*  
 Van Eaton, R. A., 403*n*  
 Van Linge, A. R., 285  
 Van Linge, T. S., 285  
 Van Nostrand Co., D., 37*n*  
 Van Schaak Bros. Chemical Works,  
 190, 192, 204, 359  
 Van Vlissingen, F. H. F., 380*n*  
 Vanadium Alloys Corp., 41, 41*n*  
 Vandalia Chemical Co., 173*n*, 185  
 Vanderhoeven, C., 380*n*  
 Van't Hof, J. H., 170*n*  
 Varnes, S. K., 203*n*  
 Vedder, E. B., 266, 272  
 \*Veillon, L., 199\*, 217*n*  
 Venable, C. S., 400  
 Vera Chemical Co., 420*n*  
 Vera Chemical Company of Canada,  
 Ltd., 420*n*  
 Vera Chemical Corp., 420*n*  
 Verein f. Chemische u. Metallurgische  
 Produktion von Anssig, 59-60  
 Vereinigte Glanzstoff Fabriken A.-G.,  
 53, 380  
 Verona Chemical Co., 305  
 Vick Chemical Co., 298  
 Victor Chemical Works, 35*n*, 103, 107,  
 512, 518, 537  
 Vietor, C., 284*n*  
 Vietor & Achelis, 284*n*  
 Vietor & Hosken, 284  
 Vieweg, F., 324*n*  
 Vinegar Hill Zinc Co., 128*n*  
 Virginia-Carolina Chemical Co., 33,  
 101, 320, 322*n*, 327, 327*n*, 328, 512,  
 518-9  
 Virginia Cellulose Co., 40, 353, 359  
 Virginia Domestic Coke Corp., 213  
 Virginia Electric & Power Co., 87  
 Virginia Red Oil Products Corp., 413*n*  
 Virginian Power Co., 194  
 Viscoloid Co., 353  
 Viscose Co., 378, 381-3, 385*n*, 386, 388,  
 388*n*, 418, 547

- Visking Corp., 353  
 Vitalis Co., 76*n*  
 Vitamineral Products Co., 518  
 Vivaudou, V., 296  
 Vliet, D. F., 277  
 Voegtlin, C., 256  
 Vogel, 305*n*  
 Vogel, A. G., 323*n*  
 Vogelstein, L., 341*n*  
 Voight, W. L., 26*n*  
 Volstead, A. J., 151-2, 152*n*, 158-60  
 Volwiler, E. H., 255, 539  
 Vreeland, C. D., 345  
 Vulcan Detinning Co., 522  
  
 Waggaman, W. H., 96*n*, 107*n*  
 Wagner, T. B., 439  
 Wailes-Dove-Hermiston Corp., 537  
 Waksman, S. A., 316  
 Walbridge, H. D., 321*n*  
 Waldinger, C. P., 229  
 \*Walker, B., 214\*, 222  
 Walker, E. C., 122, 126  
 Walker, E. E., 362  
 Walker, G., 135  
 Walker, G. H., 164*n*  
 Walker, H. V., 189*n*  
 Walker, H. W., 346  
 Walker, R. G., 437  
 \*Walker, T. P., 183\*, 189, 428  
 Walker, W., 549  
 Walker, W. H., 435*n*  
 Walker Chemical Co., 45  
 Walker Mining Co., 341*n*  
 Wallace, E. L., 428  
 \*Wallach, R. N., 234, 343\*, 353, 549-50  
 Walsh, J. F., 427  
 Walter, A., 202  
 Walter, J. J., 68  
 Walwer, K., 259  
 Wander & Sons Chemical Co., S., 118  
 Warburg, P. M., 236  
 Ward, A. L., 431*n*  
 Warner, L. C., 123*n*  
 Warner Chemical Co., 23, 101, 103, 109, 123*n*, 124, 518  
 Warner & Co., Wm. R., 278, 286*n*, 290  
 Warner Iron Co., 518  
 Warner-Klipstein Chemical Co., 194-6  
 Warren & Co., S. D., 522  
 Warren Foundry & Pipe Corp., 518  
 Washburn, E. W., 391  
 Washburn, F. S., 43  
 Washington, Alexander & Cook, 328  
 Washington Soda Products Co., 118  
 Wassell, H. E., 343*n*, 347  
 Waterbury, C. H., 276-7  
  
 Waters, E. E., 344*n*  
 Watkins, M. W., 33*n*  
 Watkins, W. H., 238  
 Watson, F., 321*n*  
 \*Watson, J. J., 97, 118\*, 322*n*  
 Watson, W. N., 205, 225, 239, 306, 426  
 Watson Co., H. F., 222  
 Watson & Pressprich, 97*n*  
 Watts, L. A., 307  
 WBZ (Radio Station), 5  
 Wear Tar Works, Brotherton & Co., 42  
 Weaver, V. M., 202  
 Webb, E. W., 401-2, 403*n*, 407  
 Webb, M. D., 268  
 Webber, H. A., 387*n*  
 Weber, L. E., 213*n*  
 Weber, O., 40, 40*n*  
 Weber, W. C., 110  
 Webster, D., 7  
 Webster, W. J., 385  
 Weckman, F. W., 253  
 Weed, J. F., 77  
 Weed, L. A., 251  
 Weed, W. H., 339  
 \*Weeks, W. S., 55\*, 60*n*, 94, 550  
 Wehrly, C. S., 268, 273  
 Weidenhammer, R. M., 49*n*  
 Weidlein, E. R., 429*n*, 431*n*, 549  
 Weiler-ter-Meer, *see* Chemische Fabriken Weiler-ter-Meer  
 Weinberg, C. von, 52  
 Weir, J. W., 404-5  
 Weir, W. W., 314  
 Weisberg, M., 230*n*, 231  
 Weisberg Laboratories, Mark, 231*n*  
 Weismuller, F. H., 369*n*  
 Weiss, J. M., 210*n*, 213, 224-5, 436, 436*n*  
 Weiss, M. L., 410-11  
 Weiss, W. E., 236*n*, 343*n*  
 Weith, A. J., 349*n*  
 Weizmann, C., 188, 190-91  
 Welch, R. L., 390  
 Welch Chemical Co., 327*n*, 328, 519, 523  
 Wellcome Chemical Research Laboratories, 288*n*  
 Welles, E. R., 330  
 Wellman, G., 396*n*  
 Wells, A. E., 72*n*  
 Wells, P. A., 273  
 \*Wendt, G. L., 391*n*, 433, 433*n*, 438\*  
 Wesco Waterpaints, Inc., 372*n*  
 Wescott, W. B., 412*n*  
 Wesley & Co., Edward, 290  
 Wesson, D., 549

- West, C. J., 432  
 West Coast Chemical Co., 80  
 West Coast Kalsomine Co., 372*n*  
 West Disinfecting Co., 344*n*  
 West End Chemical Co., 118, 522  
 West Virginia Pulp & Paper Co., 421, 428, 522  
 Westby, G. N., 94  
 Western Carbon Co., 415  
 Western Charcoal Company, 182  
 Western Chemical Co., 211*n*  
 Western Chemicals, Inc., 129  
 Western Condensing Co., 140*n*  
 Western Creosoting Co., 211*n*  
 Western Dry Color Co., 373  
 Western Electric Co., 193*n*, 433*n*  
 Western Industries Co., 164, 181, 360, 537  
 Western Paper Makers' Chemical Co., 419, 420*n*  
 Western Salt Co., 264, 410  
 Western Sulphur Co., 80  
 Western Union Telegraph Co., 337  
 Westervelt, W. Y., 82  
 Westinghouse, Church & Kerr, 321  
 Westinghouse Electric & Manufacturing Co., 5, 357, 544  
 Weston, C. K., 403*n*  
 Westvaco Chlorine Products Corp., 35*n*, 101*n*, 123-4, 196, 264*n*, 265, 265*n*, 522  
 Wetherill Varnish Co., Geo. D., 357  
 Wattersol Dyestuffs Corp., 45  
 Wetterwald & Pfister Co., 45  
 Whaley, G. H., 550  
 Wheeler, W. B., 151, 152*n*, 159  
 Whelan, T. A., 415*n*  
 Wherrett, H. S., 427  
 Whitaker, M. C., 23, 151, 152*n*, 154, 159, 167-8, 439, 504, 549-50  
 Whitbeck Chemical Corp., 192  
 White, A. H., 539, 549  
 White, A. J., 178*n*  
 White, B. S., 371  
 White, E. C., 250  
 White, E. W., 186  
 White, J. C., 178*n*  
 White Engineering Corp., J. G., 78  
 White Heat Products Co., 191*n*  
 White Tar Aniline Corp., 232  
 White Tar Co., 23, 222  
 Whitelaw, M., 117  
 Whitelaw, R. W., 117  
 Whitelaw Bros., 115, 117  
 Whitford, E. L., 110, 130*n*  
 Whiting, G. A., 70*n*, 72, 510  
 Whiting, J., 114*n*  
 Whitman, W. C., 400  
 Whitman's, 352  
 \*Whitmore, F. C., 247\*, 252, 433*n*, 439, 549  
 Whitmore, W. F., 366*n*  
 Whitney, E., 4*n*  
 Whitney, M., 104  
 Whitney, W. R., 433*n*, 549  
 Whitney, W. T., 107*n*  
 Whitney Chemical Co., 264  
 Whittaker, C. W., 330  
 Whittier, E. S., 110  
 Whittle, C. A., 346  
 Wiarda & Co., John C., 44  
 Wiggam, D. R., 361  
 Wilckes-Martin-Wilckes Co., 103, 518  
 Wilder, S. W., 10*n*, 11-12, 23, 42, 47, 60*n*, 504, 549-50  
 Wiley, H., 304  
 Wilhelm Co., A., 373  
 Wilkins & Co., Oliver, 57  
 Willard, F. W., 433*n*, 549  
 Willard, H. H., 108  
 Williams, A., Jr., 435*n*  
 Williams, C. C., 330  
 \*Williams, C. K., 359\*, 419*n*  
 Williams, E. C., 406  
 Williams, G. A., 417*n*  
 Williams, R. C., 84  
 Williams, R. R., 193, 201  
 Williams, W. H., 332, 535-6  
 Williams Co., C. K., 372  
 Williams Company of California, C. K., 373  
 Williamsburg Chemical Co., 45*n*, 231  
 \*Williamson, B. F., 359\*, 365, 365*v*, 366, 545-6  
 Willis, F. B., 321  
 Willson, C. O., 406  
 Willson, T. L., 105  
 Wilmot, H. F., 239  
 Wilson, A. L., 428  
 Wilson, C. G., 322*n*  
 Wilson, H. M., 356*n*  
 Wilson, L. A., 322*n*  
 Wilson, M. R., 539  
 Wilson, O., 29, 225, 295*n*, 361, 429*n*  
 Wilson, R. E., 399-400, 401*n*, 407  
 Wilson, W., 7, 240-41  
 Wilson, W. C., 359, 544  
 Wilson & Geo. Meyer Co., 29  
 Wilson & Toomer Fertilizer Co., 322*n*, 327*n*, 513, 519  
 Wing & Evans, 115, 117  
 Winkelman, H. A., 412*n*  
 Winkler, E., 26*n*, 420*n*  
 Winkler & Bro., Isaac, 115, 420*n*

- Winslow, C.-E. A., 213, 403*n*  
 Winston, A. W., 146  
 Wintershall A.-G., 55*n*, 324*n*  
 Winthrop Chemical Co., 246-8, 286, 343  
 Wirbelaver, W. L., 417  
 \*Wischhusen, J. F., 326\*, 342*n*  
 \*Wishnick, R. I., 416, 422\*  
 Wishnick-Tumpeer, Inc., 416  
 Witbeck Chemical Corp., 164, 537  
 Witco Chemical Co., 416  
 Witherspoon, R. A., 183  
 Withrow, J. R., 549  
 Wizeman, W. J., 13  
 WJZ (Radio Station), 5  
 Wohl, A., 208, 219  
 Woldenberg, M., 416*n*  
 Wolf, A. G., 77*n*  
 Wolf, H., 68-69, 510-11  
 Wolf & Co., Jacques, 424  
 Wolff-Alport Chemical Corp., 410, 537  
 Wolters, F. C., Jr., 116  
 Wood, A., 256  
 Wood, W. A., 368*n*  
 Wood, W. R., 153  
 Wood Chemical Products Co., 356*n*, 414  
 Wood Distillers Corp., 181  
 Wood Iron & Steel Co., Alan, 518  
 Wood Products Co., 174  
 Woodruff, E. G., 74  
 Woodruff, J. C., 95, 177*n*, 186  
 Woods, F. Z., 303  
 Woods Sons Co., Henry, 373  
 Woodward, Van L., 410  
 Woodward, W. C., 282*n*  
 Woodward & Co., Allaire, 303*n*  
 Woonsocket Rayon Corp., 379, 547*n*  
 Worrell Manufacturing Co., 344*n*  
 Woskresensky, 286*n*  
 Wotherspoon, R., 299*n*  
 Wraith, W., 370*n*  
 Wrench, J., 26*n*, 158*n*, 437*n*  
 Wrenshall, R., 292  
 Wright, F. W., 124*n*  
 Wright, J. P., 388  
 Wright Aeronautical Corp., 399  
 Wroth, J. S., 331  
 Würtz, C. A., 197*n*  
 Wuichet Fertilizer Co., 327*n*, 519  
 Wulbern Fertilizer Co., 519  
 Wunderlich, E., 389  
 Wyeth & Bro., John, 154*n*, 183*n*, 192  
 Wyeth Chemical Co., 290  
 Yamanashi, G., 283  
 Yant, W. P., 403  
 Yaryan Rosin & Turpentine Co., 40  
 Yates, E. A., 346  
 Yeatman, P., 82*n*  
 Yerkes, L. A., 352, 378, 388  
 York Chemical Works, 513, 519  
 Young, C. O., 197*n*  
 Young, C. Y., 88*n*  
 Young, G. J., 84, 145  
 Young, H. C., 84  
 Young, H. D., 347  
 Young, H. H., 250  
 Young, J., 392*n*  
 Young Aniline Works, 229  
 Youngken, H. W., 273  
 Youngstown Sheet & Tube Co., 72, 518  
 Zeisberg, F. C., 549  
 Zenith Furnace Co., 518  
 Zimmer, B. W., 371*n*  
 Zimmer, C., 355*n*  
 \*Zinsser, F. G., 60*n*, 230\*, 232, 550  
 Zinsser, H., 232*n*  
 Zinsser, J. S., 232*n*  
 Zinsser, R., 232*n*  
 Zinsser, W. H., 232*n*  
 Zinsser & Co., 232  
 Zinsser & Co., Wm., 232*n*  
 Zobel, A. G., 232  
 Zobel, E. L., 232  
 Zobel Co., Ernst, 232  
 Zoffman, G. F., 77  
 Zoph, N. M., 372



## SUBJECT INDEX

Statistics (tariff, prices, imports, exports, production, etc.) indicated by italics.

- Abel Fund for Research on the Common Cold, John J., 288
- Abrasives, 441, 523
- Accelerators, for rubber, 43, 183, 221, 410-14
- Acele, 383
- Acenaphthene, 441, 467
- Acetaldehyde, 183, 200, 270, 441, 451-2, 467, 528
- Acetaldol, 183, 441, 470
- Acetanilide, 221, 255, 274*n*, 441, 451-2, 467, 528
- Acetate rayon, 237, 381-4, 539, 547
- Acetates, 166, 182, 192, 194, 200
- Acetic acid, 10, 19, 178-80, 182-4, 190, 200, 377, 441, 451-2, 467, 495, 525, 548; synthetic, 127, 173-4, 182-4, 215*n*, 216*n*, 429
- anhydride, 184-5, 305*n*, 377, 441, 451-2, 467, 525
- Acetone, 19, 31, 173, 175, 178*n*, 182, 184, 193, 196, 198, 201, 351, 377, 404, 441, 451-2, 467, 495; fermentation, 88, 188-91; synthetic, 127, 173
- oil, 201, 441
- Acetphenetidine, 255, 441, 467
- Acetyl radical, 184
- Acetylene, 41-42, 183, 183*n*, 200, 429
- tetrachloride, 199, 199*n*, 200
- Acetylsalicylic acid, *see* Aspirin
- Acheson medal, 122*n*, 141*n*
- Acid black 10B, 528
- "Acid oil," 391*n*
- Acid phosphate, *see* Superphosphate
- Acids, 26, 173, 265, 358, 441, 450, 469-70, 495, 544
- Acrylate resins, 87, 354
- Addiction, 247, 281
- Adhesives, 143, 387, 412, 449
- Adonite, 441
- Adulteration, of drugs, 280
- Advertising, chemical, 25, 28, 167; cosmetic, 294-5; drug, 276
- Africa, copper, 340; mint, 299
- Agalma black 10B, 528
- Agar-agar, 424
- Agate, imitation, 349
- Agricultural Adjustment Act, 322*n*
- Agricultural Insecticide & Fungicide Manufacturers' Association, 344
- Agriculture, chemicals for, 40*n*, 81; chemicals from wastes of, 350, 386-7, 544-5; *see also* Cellulose; Chemistry; Furfural
- Agriculture Department, 90-91, 130, 219*n*, 238, 280, 296, 298, 313, 332, 333*n*, 337, 350, 355, 364*n*, 544
- Airplane, dopes, 188; fuels, 397-8; motor-cooling agents, 197
- Alabama, bauxite, 132
- Alabama Polytechnic Institute, 423
- Alabama University, 336, 421, 423
- Aladdinite, 354
- Alchlor process (lubricating oils), 134
- Alcohol, 5, 10*n*, 12, 19, 31, 38, 54, 121, 127, 151-68, 181, 184, 190, 190*n*, 195, 198, 203, 257, 270-71, 287, 303*n*, 377, 387, 424, 441, 443, 449, 453-4, 470, 495, 525; denatured, 151-2, 154-9, 197, 199, 272, 377, 453-4, 470, 525, 548; synthetic, 127, 163, 167, 199-200
- Alcohol Trades Advisory Committee, 154-5
- Alcohols, 171, 177, 193*n*, 194, 201, 271, 298*n*, 358, 422, 441; higher, 39, 39*n*, 87, 391*n*, 392*n*
- Aldehol, 156-7
- Aldehyde ammonia, 441
- Aldehydes, 156*n*, 173, 183, 270-71, 349, 351, 357, 414
- Aldol, 270, 412, 441, 470
- Aldur, 354
- Algae, 339, 354
- Algiers, phosphate rock, 99-100
- Algin, 424
- Alien Property Custodian, 8, 239-40, 246-7, 253-4, 258, 324*n*, 411, 539
- Aliphatic compounds, 40, 42, 127, 188*n*, 194, 197-9, 323, 332, 342-3, 392
- Alizarin, 219, 441, 470; dyes, 232, 470; red, 58; rubinol 3G, 340

- Alkalies, 12, 24, 35, 38, 46<sub>n</sub>, 127, 144, 212, 259, 327, 371, 409, 441, 521, 544; electrolytic, 56, 93, 111-26, 377, 417, 419, 520-22; European industry, 55, 58, 60; *see also* Potassium hydroxide; Sodium hydroxide
- Alkaloids, 34, 247, 282-7, 289, 289<sub>n</sub>, 343, 441
- Alkyd resins, 245, 354, 358
- Alkylation, of petroleum, 396
- Alkylenediamines, 442
- Alkyls, metallic, 398
- Allied Committee of Alcohol Users, 153<sub>n</sub>
- Allonal, 248
- Alloys, 5, 92, 138, 140-41, 442
- Allyl alcohol, 173  
chlorohydrin, 122
- Allylisopropylbarbituric acid, 248
- Alpha cellulose, 386-7
- Alpha Fibre, 386
- Alum, 20-21, 50, 60, 102-3, 129, 131<sub>n</sub>, 135, 354, 419, 446, 453-4, 486; *see also* Ammonia alum
- Alumina, *see* Aluminum oxide
- Aluminum, 59, 94, 131-3, 138, 142, 144, 157<sub>n</sub>, 202, 319, 442, 470, 523  
chloride, 121, 132-5, 202, 219, 394, 398, 429, 453-4  
compounds, 450, 470  
hydroxide, 122<sub>n</sub>, 131<sub>n</sub>, 442, 453-4, 470  
oxide, 68<sub>n</sub>, 87, 93, 115, 131  
silicate, 136  
-silicon, 442  
stearate, 271, 453-4  
sulfate, 45, 135, 377, 442, 453-4, 470-71, 495, 548
- Alums, 45, 450
- Alunite, 68<sub>n</sub>
- Amberol, 357
- Ambertol, 357
- American Association for the Advancement of Science, 435
- American Association of Textile Chemists & Colorists, 238, 417
- American Bureau of Metal Statistics, 340
- American Chemical Industry Tercenary, 11<sub>n</sub>
- American Chemical Society, 10, 39<sub>n</sub>, 117<sub>n</sub>, 122<sub>n</sub>, 125<sub>n</sub>, 153<sub>n</sub>, 200<sub>n</sub>, 202<sub>n</sub>, 211<sub>n</sub>, 212<sub>n</sub>, 216<sub>n</sub>, 228<sub>n</sub>, 238, 241, 252<sub>n</sub>, 266<sub>n</sub>, 350<sub>n</sub>, 352<sub>n</sub>, 388, 390, 399<sub>n</sub>, 400-401, 402<sub>n</sub>, 411, 413<sub>n</sub>, 419<sub>n</sub>, 423<sub>n</sub>, 432-6, 438<sub>n</sub>, 439<sub>n</sub>, 549
- American Chemistry* (Hale), 266<sub>n</sub>
- American Conference of Pharmaceutical Faculties, 435
- American Cotton Growers' Association, 336
- American Drug Manufacturers' Association, 153-4, 254<sub>n</sub>, 279-80, 282<sub>n</sub>, 287-8
- American Dyes Institute, 240, 539
- American Electrochemical Society, 122, 122<sub>n</sub>, 223, 435, 439<sub>n</sub>
- American Farm Bureau Federation, 320-21
- American Gas Association, 313
- American Hardwood Manufacturers' Association, 9
- American Institute of Chemical Engineers, 122<sub>n</sub>, 133<sub>n</sub>, 153<sub>n</sub>, 435, 439<sub>n</sub>, 549
- American Institute of Chemists, 386<sub>n</sub>, 435-6, 439<sub>n</sub>, 549; medal, 252<sub>n</sub>, 386<sub>n</sub>
- American Institute of Mining & Metallurgical Engineers, 78<sub>n</sub>, 99<sub>n</sub>, 370<sub>n</sub>, 397<sub>n</sub>
- American Institute of New York medal, 423<sub>n</sub>
- American Journal of Clinical Medicine*, 259<sub>n</sub>
- American Manufacturers of Toilet Articles, 153<sub>n</sub>, 154, 296
- American Medical Association, 246, 251<sub>n</sub>, 282<sub>n</sub>, 284
- American Medical Editors Association, 253<sub>n</sub>
- American Paint Journal*, 344
- American Paint & Varnish Manufacturers' Association, 365-6, 373
- American Paper & Pulp Association, 355
- American Perfumer*, 304<sub>n</sub>
- American Petroleum Institute, 390-91
- American Pharmaceutical Association, 154, 275, 282<sub>n</sub>, 288<sub>n</sub>, 437
- American Pharmaceutical Manufacturers' Association, 154, 279-80, 287, 437
- American Physical Society, 432
- American Society of Agronomy, 316
- American Society of Mechanical Engineers, 377
- American Society for Testing Materials, 374
- American Tariff League, 11<sub>n</sub>
- American Zinc Institute, 370
- Amines, 198, 332, 414, 442
- Aminoanthraquinone, 442, 472;  $\beta$ -, 220
- Aminobenzoic acid, 441
- p*-Aminochlorophenol, 224

- p*-Aminodimethylaniline, 412  
 Aminodiphenyl, 223  
 Aminoisobutyronitrile, 333  
 Aminonaphthol, 422, 471  
 1-Amino-2-naphthol-4-sulfonic acid, 528  
 Aminophenetole, 442, 471  
 Aminophenol, 442, 471; *p*-, 221, 223, 453-4  
 Aminosalicyclic acid, 441  
 Ammonia, 21, 31, 71, 121, 171, 230*n*, 318-9, 412, 425, 495, 515, 548; anhydrous, 71, 85, 87, 90, 176, 221, 317, 442, 453-4, 471, 495, 515, 541; aqueous, 71, 85, 90, 92, 211, 217, 311, 317, 453-4, 515, 536, 541; oxidation, 39, 91-94, 128; synthetic, 31, 36-38, 44, 46, 52, 56, 58, 85-94, 112, 121, 127, 143, 170-72, 176-7, 313, 313*n*, 314, 317, 326, 429  
     aldehyde, 471  
     alum, 135, 442, 453-4, 471  
 Ammonia-soda process, 56, 111-5, 118, 123, 520, 522  
 Ammoniates, natural, 313  
 Ammonium acetate, 85  
     aluminum sulfate, 442  
     bicarbonate, 143, 210, 442, 471  
     carbonate, 85, 442, 453-4, 471  
     chloride (sal ammoniac), 85, 143, 210, 424, 442, 453-4, 471  
     chloroplatinate, 70  
     compounds, 90, 143, 411, 495-6, 515  
     nitrate, 85, 442, 453-4, 471, 541  
     perchlorate, 442, 471  
     persulfate, 143  
     phosphates, 43, 101, 105-7, 317, 321, 442, 453-4, 471, 518  
     sulfate, 56, 81, 85, 209, 213-4, 265, 313-4, 442, 453-4, 471, 496, 515*n*  
     sulfate-nitrate, 53, 317, 471, 515*n*  
     sulfide, 221  
 Ammonolysis, 536  
 Ammo-Phos, 43, 93  
 Ammunition, census, 449  
 Amyl acetate, 188-9, 191-2, 201, 442, 453-4, 471, 495, 528  
     alcohol, 158, 188-9, 191-2, 199, 441, 453-4, 470, 528  
     chloride, 192  
     compounds, 121  
     heptate, 297  
     nitrate, 442  
     salicylate, 528  
 Amytal, 248  
 Analgesia, 269  
 Andalusite, 136  
 Andrew's Liver Salt, 290  
 Anesthetics, 203, 269-70, 287  
 Anethole, 442, 471  
 Anhydrides, 442, 469-70, 495  
 Aniline, 61*n*, 121, 207-8, 215*n*, 221, 233, 245, 261, 332*n*, 398-401, 412-3, 534, 536  
     oil, 10, 442, 453-4, 472, 496, 528  
     salt, 442, 453-4, 472  
*Annual Survey of American Chemistry*, 432  
 Anthracene, 68, 208, 219, 232, 442, 453-4, 472; dyes, 232; oil, 442, 472  
 Anthraquinone, 122, 134, 219-20, 233, 442, 453-4, 472; vat blue GCD, 528  
 Anti-freeze, 5, 21, 41, 163, 166, 184, 197, 203, 410  
 Anti-knock compounds, 127, 261; *see also* Tetraethyl lead  
 Antimony, 442, 472  
     oxide, 442, 472  
     -potassium tartrate, 442  
     sulfide, 442, 453-4, 472, 540  
 Anti-Narcotic Act, 279, 283  
 Antioxidants, petroleum, 391, 391*n*, 394; rubber, 183, 412, 413*n*  
 Antipyrine, 255, 442, 453-4, 472  
 Anti-Saloon League, 151-2, 159  
 Antiseptics, 245, 250-51, 253*n*, 254, 279, 289*n*, 290  
 Antitoxins, 289*n*  
 Anti-trust laws, 24, 31-32, 34, 36, 50, 281, 314; *see also* Clayton Act; Sherman Anti-Trust Act  
 Anti-trust suits, fertilizers, 329; po-ash, 323; quinine, 284-6  
 Antox, 412  
 Apatite, 100*n*, 446  
 Aphids, control of, 352-3  
 Apomorphine hydrochloride, 287*n*  
 Apparatus, chemical, 22, 34, 67, 191, 228, 371, 394, 437-8  
 Apple scab, control of, 341  
 Apricot pits, carbon, 181  
 Arabinose, 442  
 Arbitration Act, 9  
 Arbitration Society of America, 26  
 "Arcadian" sodium nitrate, 87  
 Arecoline hydrobromide, 287*n*  
 Arizona, sodium sulfate, 129  
 Argentina, tariff, 61*n*  
 Argols, 442, 453-4, 472  
 Arkansas, bauxite, 44, 132  
 Arkansas University, 266  
 Arochlors, 223

- Aromatics, 3, 34, 253, 284*n*, 295-7, 301-2, 304, 306, 356, 433, 443; *see also* Cosmetics; Flavors; Perfumes  
 Arsanilic acid, 441  
 Arsenic, 102, 249, 334-8, 442, 472, 548 acid, 441, 467  
   compounds, 249-50, 252, 338, 439, 489, 543  
   oxides, 334*n*  
   red, 453-4  
   sulfide, 442, 472  
   trioxide, *see* White arsenic  
 Arsenicals, *see* Arsenic compounds  
 Arsen(i)ous acid, *see* White arsenic  
*p*-Arsono-N<sup>a</sup>-phenylglycinamide, sodium, 249  
 Arsphenamine, 131, 246*n*, 247-50, 259, 442, 489  
 Artichokes, sugar, 423  
 Artificial Silk Manufacturers' Association, 153*n*  
 Asphalt, 416*n*  
 Aspirin, 246-7, 254-5, 274*n*, 290, 442, 451-2, 467, 528  
 Assay, biological, 250, 275-6, 287-8, 422, 434  
 Associate Grocery Manufacturers of America, 386*n*  
 Associated Industries of Alabama, 106*n*  
 Association of American Railroads, 125*n*  
 Association of American Soap & Glycerin Producers, 422  
 Association of Cinchona Bark Producers (Java), 285*n*  
 Association of Consulting Chemists & Chemical Engineers, 125*n*, 436  
 Association of Equipment Manufacturers, 438  
 Association of Official Agricultural Chemists, 386*n*  
 Associations, export, 60  
 Astringents, 142  
 Atomic structure, 399  
 "Atomic" sulfur, 341  
 Atophan, 246*n*, 255  
 Atropine, 287*n*, 472; sulfate, 287  
 Auramine, 231, 528, 538-9  
 Australia, eucalyptus, 299; lead, 371; phosphate, 100-101  
 Austria, chemical industry, 48, 58; magnesite, 139  
 Automobile industry, 4-7, 19, 36, 40*n*, 46, 142, 188-9, 191, 295, 337, 339, 357, 359, 373, 392, 396-7, 402, 404; *see also* Anti-freeze; Fuels; Gasoline; Tetraethyl lead  
 Aviation fuels, 397-8  
 Azides, 442  
 Azo dyes, 222, 228, 231, 238  
 Azo yellow, 231  
 Bacteria, fermentation, 188-9; pathogenic, 248-9  
 Bacteriophages, 189*n*  
 Bagasse, pressed board, 419; furfural, 544  
 Baking industry, 103, 305, 424  
   powder, 101-3, 107, 107*n*, 124, 127, 424, 449, 496  
   soda, *see* Sodium bicarbonate  
*Baking Powder Controversy* (Morrisson), 11*n*  
 Ball clays, 421  
 Barbitol, *see* Diethylbarbituric acid  
 Barium, 138, 369  
   alloys, 442  
   carbonate, 138, 442, 453-4, 473, 523  
   chloride, 442, 455-6, 473, 523  
   compounds, 29, 124, 136-8, 194-5, 523-4  
   dioxide, *see* Barium peroxide  
   fluosilicate, 341  
   hydroxide, 442, 473  
   nitrate, 442, 473  
   oxide, 138, 355, 420, 442  
   peroxide, 13, 136*n*, 137*n*, 417, 442, 473, 524  
   sulfate, 136-8, 367, 442, 473; *see also* Barytes; Blanc fixe  
   sulfide, 524  
 Bark, medicinal, 247  
 Barytes, 18, 136-7, 355*n*, 367, 372, 442, 455-6, 473, 524, 546*n*  
 Basic fuchsin, 238  
 Basisporium, control of, 343  
 Batteries, 41-42, 143, 371, 521  
 Bauxite, 44, 131-6, 200, 442, 470, 473, 496, 523  
 Bayer 205, 249  
 Bean beetles, control of, 341  
 "Beetle," 44, 354  
 Beets, alcohol, 160; sugar, 288, 423  
 Belgian Congo, copper, 340  
 Belgium, 15; alkalis, 58; ammonia, 93, 313; phosphate rock, 100; rayon, 381; sulfuric acid, 70  
 Benochlor, 200*n*  
 Bentonite-sulfur, 341  
 Benzalchloride, 442  
 Benzaldehyde, 122, 210, 442, 455-6, 473, 484, 538  
 Benzanthrone, 442, 473  
 Benzedrine, 540

- Benzene, 5, 10, 134, 155, 207-8, 214, 217, 219, 398, 401, 404, 442, 455-6, 473, 496, 534; compounds, 127, 534; toxicity, 213-4; *see also* Fuels  
 Benzoic acid, 121-2, 255, 358*n*, 441, 451-2, 468  
 Benzol, motor, *see* Fuels  
 Benzol Committee, National Safety Council, 213-4  
 Benzoquinone, 442  
 Benzoyl chloride, 442  
 Benzyl acetate, 442, 528  
     alcohol, 528  
     benzoate, 442, 529  
     chloride, 210, 442, 455-6, 474  
     succinate, 297  
*p*-Benzylaminophenol, 394  
 Benzylethylaniline, 442, 478  
 Berlin blue, 474  
 Berries, medicinal, 247  
 Beryllium, 420, 442  
 Betaine hydrochloride, 288  
 Beverages, nonalcoholic, 425, 426*n*  
 Big Creek Dome, sulfur, 76  
 Big Hill Dome ("Old Gulf"), sulfur, 73-75, 78  
 Biochemistry, 251  
 Biologicals, 46, 259, 289, 289*n*, 434  
 Biology, 251  
 Birdseye foods, 425  
 Birmingham University (Eng.), 395  
 Bismarsen, 249  
 Bismuth, 50, 249, 271, 442, 474  
     arsphenamine sulfonate, 249  
     compounds, 442, 474  
     subnitrate, 455-6  
 Black pigments, 442, 486  
     powder (gunpowder), 39, 445  
 Blacking, 449  
 Blanc fixe, 136*n*, 137, 442, 455-6, 473, 524  
 Blast furnace, 96, 106*n*, 107, 178; products, 517  
 Bleaching compounds (powder), 4, 19, 25, 28, 112, 115, 118-22, 125, 131, 417, 442, 450*n*, 455-6, 474, 496; *see also* Chlorine  
 Blood, plastics, 354  
 Blue pigments, 442, 474, 497  
     vitriol, *see* Copper sulfate  
 Bluing, 449  
 Boiler-water treatment, 131  
 Boling Dome, sulfur, 77-78  
 Boll weevil, control of, 333-7, 341  
 Bonderite, 108  
 Bone black, 442, 449, 496  
     distillates, 515  
     phosphates, 99-100, 102-3, 107  
 Bookbinders' Guild, 417  
 Borates, 442, 473  
 Borax, 127, 144-5, 271, 323, 442, 455-6, 474, 496  
 Bordeaux mixture, 338*n*, 344, 455-6  
 Boric acid, 144-5, 441, 451-2, 468, 495  
 Boron, alloys, 442  
     carbide, 443  
 Borozone, 216*n*  
 Bottles, 26, 352, 420  
 Boxboard, adhesives, 143  
 Brady Clinic, Johns Hopkins University, 250  
 Bran products, 191, 350  
 Branded drug goods, 275-7  
 Brazil, rubber, 409; tariff, 61*n*  
 Bread, en'ched, 424  
 Brewer's pitch, 232  
 Briand-Kellogg Pact, 15  
 Brilliant blue FCF, 231  
     green, 231, 539  
 Brines, alkalies, 118, 265-7; borax, 144-5; bromine, 261, 264-5; electrolysis, 113; magnesium chloride, 139; potash, 54, 145, 322, 324-5  
 British Copper Sulphate Association, 339  
 British Guiana, bauxite, 131-2  
 Bromides, 260, 263  
 Bromine, 19, 127, 260-65, 400, 404, 443, 455-6, 474; compounds, 474  
 Bromine Convention (Ger.), 263  
 Bromobenzene, 443, 534-5  
 Bromoethylene, *see* Ethylene dibromide  
 Bromo-Seltzer, 264, 434  
 Bronchitis, chlorine for, 266  
 Bronze, 109  
 Brown pigments, 372, 474  
 Brown University, 402*n*  
 Bryannound, sulfur, 74, 75*n*, 76-78  
 Buffalo University, 434  
 Bulgaria, tariff, 61*n*  
 Buramic Sales Agency (quinine), 286  
 Bureau of Social Hygiene, Inc., 281*n*  
 Burns, remedies, 251  
 Butadiene, 189*n*  
 Butane, 195, 195*n*, 209-10, 204-5  
 Butanol, *see* Butyl alcohol  
 Butesin, 251

Butler University, 211*n*  
 Buttons, plastic, 354, 544  
 Butyl acetate, 184, 188-9, 200, 201, 443, 455-6, 474, 495, 529; *sec.*-, 193, 529  
   alcohol, 127, 158, 167, 173, 176, 184, 190, 194, 199, 398, 429, 441, 453-4, 470, 529; fermentation, 88, 93, 188-9, 190-91, 201; *sec.*-, 193, 201  
   *p*-aminobenzoate, 251  
   Carbitol, 198  
   Cellosolve, 198  
   compounds, 190  
   formate, *sec.*-, 342  
   phenyl acetate, 297  
   propionate, 260, 529  
   stearate, 271  
   tartrate, 271  
*p*-Butylaminophenol, 394  
 Butylethylbarbituric acid, 248  
 Butylpyrrolidine, 332  
 Butylene chlorohydrin, 443  
   dichloride, 443  
   glycol, 443  
 Butyraldehyde, 190, 412, 443, 474

Cacao, 286  
 Cadman medal, 396*n*  
 Cadmium, 220, 369, 443, 474  
   lithopone, 369  
   sulfide, 455-6  
 Caffeine, 286-7, 443, 455-6, 475  
   citrate, 287, 443  
   salts, 475  
   sodium benzoate, 287*n*  
 Calcite, 328  
 Calcium, 369, 446, 475; alloys, 442  
   acetate, 169-70, 172-3, 175, 178, 182-3, 201, 443, 455-6, 475, 496, 525  
   aluminate, 136  
   arsenate, 25, 333-8, 341, 344, 443, 455-6, 475, 496, 543  
   borate, 443  
   carbide, 105, 182-3, 443, 475, 496  
   carbonate, 144  
   chloride, 264-5, 443, 455-6, 475, 496  
   citrate, 269, 475, 482  
   cyanamide, 43-44, 58, 86, 318-20, 443, 455-6, 475, 515*n*  
   cyanide, 43, 342  
   ethylisopropylbarbiturate, 248  
   fluoride, 445, 479  
   hypochlorite, 112, 118, 121, 202  
   molybdate, 443  
   nitrate, 53, 317*n*, 443, 475, 515*n*  
   oxalate, 443

Calcium phosphates, 99*n*, 101, 103-5, 127, 455-6, 516, 518  
   salts, 424  
   sulfate, 325, 367, 443, 489  
   tartrate, 443  
 Caldwell's Syrup of Pepsin, Dr., 247*n*  
 Caliche, 267, 315-6  
 California, andalusite, 136; borax, 145, 271*n*; citrus industry, 89, 269; cotton, 360; fertilizers, 28; hydrogen cyanide, 89, 342; iodine, 267; mercury, 268; mint, 298; petroleum, 394, 405; potash, 54; sodium sulfate, 128; sulfur, 80; trona, 102  
 California Citrus League, 269, 428  
 California Institute of Technology, 434  
 California Menthol Growers' Association, 298  
 California University, 81  
 Calomel, 267, 443, 459-60, 483  
 Calorimeters, 212*n*  
 Calurea, 317*n*  
 Cambria Mine (mercury), 268  
 Cambridge University (Eng.), 433  
 Campho-Phenique, 216*n*  
 Camphor, 12, 31, 298-302, 304, 305*n*, 351, 398, 443, 455-6, 475; oil, 301*n*  
 Camphorated oil, 287  
 Canada, acetic acid & acetone, 174, 182, 184; arsenic, 338; chlorine, 119*n*; ephedrine, 284; nickel, 340; sulfur, 81  
 Candles, 222, 449  
 Carbazole, 443, 475; dyes, 472  
 Carbides, 41-42, 58-59  
 Carbitol, 198  
 Carbohydrate Laboratory, Bureau of Chemistry, 423  
 Carbohydrates, 422; resins, 544  
 Carbon, 42, 96*n*, 133, 135, 171, 181, 211, 223, 399, 442-3, 535; activated, 58, 195, 443  
   bisulfide, 195, 202, 342, 377, 455-6  
   black, 190*n*, 414-6, 442, 449, 455-6, 497  
   dioxide, 102, 139, 176-7, 190, 318, 343, 443; solid, 425-6  
   monoxide, 170, 176, 194, 199  
   tetrachloride, 120, 127, 195, 199, 199*n*, 202, 333, 342, 401, 425, 443, 455-6, 475, 529  
 Carbon Black Export Association, 416  
 Carbonates, 100*n*  
 Carbonization, 211, 214, 217  
 Carbonizer, 122*n*  
 Carboxide, 343  
 Carnallite, 325

- Carnegie Foundation, 252*n*  
 Carnegie Institute of Technology, 156  
 Cartels, 12-13, 32, 48-63; copper, 340;  
   nitrogen, 312-4; pyrites, 82; qui-  
   nine, 284-6; zinc, 370-71  
*Cartels, Concerns and Trusts* (Lief-  
   mann), 50*n*  
 Cartons, 143, 275, 418  
 Carvacrol, 201  
 Casale process (ammonia), 37, 87-88, 319  
 Case-hardening compounds, 138  
 Casein, 419, 443; plastics, 354  
 Cassel brown (earth), 474  
 Castoria, 247*n*  
 Catalin, 349  
 Catalysts, 44, 80, 89, 184, 219*n*, 220-21,  
   351, 368, 429, 433; for alcohols,  
   170*n*, 171, 176-7, 199, 201; copper,  
   176*n*, 535; cracking, 391, 396, 398-  
   9, 404; iron, 80, 86-87, 89, 93;  
   platinum, 41, 68, 68*n*, 70, 91-93,  
   509; vanadium, 41, 45, 67-70, 510-  
   11  
 Cattledip, 217  
 Caustic potash, *see* Potassium hydro-  
   xide  
   soda, *see* Sodium hydroxide  
 Celanese, 383  
 Celastic, 353  
 Celestite, 492  
 Cellophane, 38, 351-3  
 Cellosolve, 196-8, 200  
   acetate, 198  
 Celluloid, 300, 386, 499  
 Cellulose, 29, 68, 122, 125, 348, 349*n*,  
   351, 352*n*, 353, 377, 383, 384*n*, 386-  
   8, 399, 418-9, 429, 510, 544; alpha,  
   386-7; derivatives, 36, 40, 56, 359;  
   *see also* Film; Lacquers; Nitro-  
   cellulose; Plastics; Rayon  
   acetate, 178, 182, 184, 237, 351, 353,  
   382-3, 443, 455-6  
   esters, 443, 488  
   ethers, 443  
 Cel-O-Seal, 352  
 Cement, 135-6, 139, 358, 523; potash,  
   54, 323-4  
 Cement Manufacturers' Protective As-  
   sociation, 9  
*Census of Dyes* (Tariff Commission),  
   10*n*, 239, 297  
 Centrifuges, 191, 404  
 Ceramics, 420, 480, 548  
 Cerium, 443  
   fluoride, 443, 476  
   nitrate, 443, 476  
   salts, 476  
 Cesium, 443  
 Chacelon, 384  
 Chain stores, drug, 27, 275-7  
 Chalk, 443  
 Chandler Laboratories, 435, 439  
 Chandler medal, 193*n*, 212*n*  
 Channel black, 416, 416*n*  
 Charcoal, 170, 172-4, 178-80, 181*n*, 182,  
   186, 405, 443, 449  
 Chars, 442  
 Chaulmoogra esters, 540  
   oil, 287-8  
 Cheese, 424  
*Chemical Abstracts*, 549  
 Chemical Advisory Committee, Depart-  
   ment of Commerce, 10-13, 60-61  
*Chemical Age* (N. Y.), 436, 439  
 Chemical Alliance, 290*n*  
 Chemical Clubs (Chicago, etc.), 26  
*Chemical, Color & Oil Record*, 439  
 Chemical Division, Bureau of Foreign  
   & Domestic Commerce, 10*n*, 11-13,  
   61*n*, 173, 239  
 Chemical economics, 433-4  
 Chemical engineering, 34, 431, 435-7,  
   548  
*Chemical Examination of Water, Fuel,  
   Flue Gases and Lubricants* (Parr),  
   212*n*  
 Chemical Exposition, 26*n*, 192, 204,  
   437-8, 538  
 Chemical Foundation, 171*n*, 238-41,  
   288, 430*n*, 435*n*, 539  
*Chemical Industries*, 116*n*, 125*n*, 252*n*  
 Chemical Industry medal, 413*n*, 439*n*  
*Chemical Markets*, 36*n*, 317, 439  
*Chemical & Metallurgical Engineering*,  
   140*n*, 218, 435*n*, 439, 504  
 Chemical Warfare Service, 26, 34, 266,  
   337, 342, 403, 413, 438-9  
 Chemicalization of industry, 408-28  
 Chemicals, alkalies for, 521; bauxite  
   for, 523; census, 449-50; consump-  
   tion, 429-30; C. P., 259; duties,  
   441-8; exports, 495-501; imports,  
   467-94; inorganic, 34, 37, 66-147;  
   organic, 29, 119*n*, 123, 127, 131,  
   135, 151-256, 267, 280, 296-7, 332,  
   433, 433*n*, 526-34, 535-7; phosphate  
   rock for, 517; prices, 451-66; sul-  
   furic acid for, 510; world output,  
   17-18; *see also* Coal-tar chemicals;  
   Fine chemicals; Heavy chemicals;  
   Industrial chemicals; Medicinal  
   chemicals; Photographic chemi-  
   cals; Wood chemicals; etc.

- Chemistry, 5, 26<sub>n</sub>, 251, 433; agricultural, 281, 436; cellulose, 399, 418; colloidal, 434-5; organic, 251-2; of paints, 374; perfume, 296; petroleum, 390
- Chemistry Bureau, 193<sub>n</sub>, 201, 204, 238, 269, 279, 288<sub>n</sub>, 299, 314, 350, 423, 438, 539
- Chemistry & Chemical Technology Division, National Research Council, 432
- Chemistry & Soils Bureau, 281, 287, 333, 342, 355, 386, 423, 436<sub>n</sub>, 438
- Chemistry Triumphant* (Hale), 215<sub>n</sub>
- Chemists, 34, 431, 433, 436-7
- Chemists' Club (N. Y.), 125<sub>n</sub>, 151, 211<sub>n</sub>, 232<sub>n</sub>, 252<sub>n</sub>, 430-31
- Chemotherapy, 249
- Chemurgy, 356<sub>n</sub>; 366; *see also* Agriculture; Wastes
- Chestnut extract, 421, 443, 497
- Chewing gum, 210
- Chicago University, 251-2, 403<sub>n</sub>, 539
- Chicory, inulin, 423
- Chile, borax, 145; chemical trade, 18, 18<sub>n</sub>; copper, 315, 340; iodine, 266-7, 312; nitrate, 18<sub>n</sub>, 31, 37, 50, 85, 90-91, 93-94, 101<sub>n</sub>, 127-8, 267, 311-6, 515<sub>n</sub>; tariff, 61<sub>n</sub>
- Chile Iodine Producers' Association, 312
- Chilean Nitrate Producers' Association, 312, 314, 316
- Chilean Nitrate of Soda Nitrogen Research Award, 316
- China, 15; chemical industry, 13<sub>n</sub>; mahuang, 283-4, 450; opium, 282; tung oil, 364-5
- China clay, 443
- nut (wood) oil, *see* Tung oil
- China Foundation prize, 283<sub>n</sub>
- Chinese blue, 474
- Chloral hydrate, 270, 443, 476
- Chloramine-T, 247
- Chlorides, aliphatic, 333
- Chloridization, 370
- Chlorination, 112, 120-21, 128, 133-4, 191, 199, 202, 208, 262, 266
- Chlorine, 10, 29, 31, 58, 112-5, 118-25, 133-4, 192, 194, 196, 199, 260-62, 264-6, 366, 399, 497; liquid, 25, 28, 118, 123-5, 272, 419, 455-6, 548
- cell, 87, 93, 113-4, 119-21, 125, 195
- compounds, 121, 195, 199, 199<sub>n</sub>, 260
- Chlorine Institute, 120<sub>n</sub>, 125
- Chloroacetic acid, 441, 451-2; esters, 342
- Chloroacetophenone, 342
- o*-Chloroaniline, 221
- $\beta$ -Chloroanthraquinone, 220
- Chlorobenzene, 120-21, 195, 210, 216, 216<sub>n</sub>, 221, 443, 455-6, 529, 535-6
- Chlorodiphenyl, *o*- & *p*-, 223
- Chloroform, 120, 127, 203, 270, 275, 443, 455-6, 476, 529
- Chlorophenol, *o*- & *p*-, 224
- Chlorophthalic acid, 441
- Chloropicrin, 332, 342
- Chlorosulfonic acid, 451-2
- Chrome, 142-3, 443; colors, 232, 476, 497; plating, 141-3; tanning, 33
- blue black R, 229
- blue black U, 529
- green, 443, 546
- orange, 546
- steel, 92
- yellow, 371, 443, 546
- Chromic acid, 141-3, 219, 441, 451-2, 468
- Chromite, *see* Chrome
- Chromium, 93, 442-3, 476
- carbide, 443
- chloride, 474
- nickel, 443
- oxide, 143
- silicon, 443
- sulfate, 443, 474
- trioxide, *see* Chromic acid
- vanadium, 443
- Chrysophenine, 229
- Cigarettes, vanillin in, 305
- Cinchona, 284-5, 343, 447, 474, 499
- Cinchonidine, 474
- Cinchonine, 474
- Cinchophen, 240, 246<sub>n</sub>, 255, 529
- Cincinnati University, 397<sub>n</sub>, 422
- Cinnamaldehyde, 529
- Cinnamic acid, 441, 468
- Citral, 443, 471
- Citric acid, 269, 287, 304, 358, 358<sub>n</sub>, 441, 451-2, 468
- Citronellal, 302
- Citronellol, 302
- Citrus industry, 545; chemicals from, 269; fumigants, 89, 342
- Clark University, 402<sub>n</sub>
- Claude process (ammonia), 36-37, 87-88, 90
- Clays, 135, 138, 419, 421, 421<sub>n</sub>, 443
- Clayton Act, 124<sub>n</sub>, 286, 291
- Cleanliness Institute, 422
- Cleanliness Journal*, 422
- Cleansers, 443, 449; *see also* Detergents; Polishes; Soap



- Clemens Dome, sulfur, 74  
 Cloroben, 200<sub>n</sub>  
 Cloves, 306  
 Coal, 19, 24, 131, 178, 211, 212<sub>n</sub>; carbonization, 212, 214, 217; gas, 80, 209, 212-3, 222; hydrogenation, 53, 395; products, 510  
 Coal tar, 207, 209-15, 218, 306, 377, 429, 443, 497; acids, 211, 217-9, 443  
 Coal-tar chemicals, 31, 33, 42-44, 94<sub>n</sub>, 127, 166, 207-56, 259, 269, 295-7, 300, 332<sub>n</sub>, 377, 414, 443, 450, 497, 514, 526-34; crudes, 123, 207-226, 534; intermediates, 45, 123, 134, 200, 207-226, 252, 348, 443, 497, 526; *see also* Aromatics; Dyes; Medicinals; etc.  
 Coatings, 39, 40<sub>n</sub>, 108, 181, 187-8, 192, 198, 210, 223, 299, 348, 352-4, 357, 359-60, 363, 366, 374, 419, 430, 538; *seq also* Lacquers; Paints; Varnishes  
 Cobalt, 443, 477; alloys, 442; driers, 366  
     acetate, 455-6  
     carbonyl, 404  
     linoleate, 443, 455-6, 477  
     oxide, 443, 477  
     salts, 477  
     sulfate, 443, 477  
 Coca leaves, 283  
 Cocaine, 151, 283, 444, 455-6  
 Coco-Quinine, 278  
 Codeine phosphate, 287<sub>n</sub>  
     sulfate, 457-8  
 Code of ethics, fertilizer industry, 329; naval stores industry, 356  
 Coffee, soluble, 231<sub>n</sub>  
 Coke, 80-81, 93, 209, 211, 213, 217  
 Coke ovens, beehive, 209, 213; by-product, 85, 90, 92, 207, 209-14, 217, 515, 534; gas, 80-81, 91, 209-10, 212-3, 222  
 Colcothar, 474  
 Colds, causes, 288  
 College of the City of New York, 26<sub>n</sub>, 299<sub>n</sub>  
 College of Louisiana, 397<sub>n</sub>  
 College of Pharmacy, Columbia University, 252, 253<sub>n</sub>, 290<sub>n</sub>, 291<sub>n</sub>, 296  
 Collodion, 444, 477  
 Colloidal Chemistry Symposium (1923), 434  
 Color Laboratory, Department of Agriculture, 238  
 Colorado University, 320<sub>n</sub>  
 Colors, 45, 221, 232, 345, 360, 372-4, 419, 443, 470, 472, 476, 480, 497, 539, 546; *see also* Dyes; Pigments  
 Columbia University, 107, 141<sub>n</sub>, 193<sub>n</sub>, 233<sub>n</sub>, 252, 253<sub>n</sub>, 296, 369<sub>n</sub>, 435-6  
 Columbium, 442, 444  
 Combinación de Yodo, 266  
 Commerce Department, 8-13, 24, 26, 60-61, 280<sub>n</sub>, 320<sub>n</sub>, 323, 329, 344, 365<sub>n</sub>, 374, 438, 503, 539  
*Commercial News*, 387  
 Commission on Standardization of Biological Stains, 238  
 Committee on Chemical Research on Medicinal Substances, National Research Council, 251  
 Common scab, control of, 343  
 Compressed Gas Manufacturers' Association, 11<sub>n</sub>, 406  
 Confectionery industry, 305, 352, 423  
 Constants, chemical & physical, 432  
 Consuming industries, chemicals in, 311-440  
 Containers, 12<sub>n</sub>, 26-27, 94, 125, 143, 214, 275, 352, 356, 413, 420, 424, 505  
 Contracts, chemical, 22-25, 26<sub>n</sub>, 436, 502-6  
 Cooling agents, for motors, 197  
 Cooper Union, 299, 436<sub>n</sub>  
 Copal gum, 355  
 Copper, 19, 59, 82, 99<sub>n</sub>, 101<sub>n</sub>, 102, 176<sub>n</sub>, 311, 315, 334, 338-40, 370, 372<sub>n</sub>, 535; alloys, 442; smelter acid, 67<sub>n</sub>, 514  
     acetate, 444, 494  
     acetoarsenite, *see* Paris green  
     carbonate, 338<sub>n</sub>, 457-8  
     compounds, 260  
     iodide, 444  
     oxide, 339, 384<sub>n</sub>, 444, 477, 536  
     subacetate, 444, 494  
     sulfate, 338-9, 341, 444, 457-8, 477, 497  
 Copper & Brass Research Association, 340  
 Copper Institute, 340  
 Copperas, *see* Ferrous sulfate  
 Cordite, 175, 182  
 Corn, 343, 423, 429; alcohols, 88, 160-61, 163, 176, 184, 191; oil, 191  
 Corn Industries Research Foundation, 423<sub>n</sub>  
 Corncobs, cellulose, 387; furfural, 350, 544-5  
 Cornell College, 419<sub>n</sub>  
 Cornell University, 260

- Cornstalks, cellulose, 387; paper, 202; xylose, 423  
 Corrosive sublimate, 444, 459-60, 483  
 Corundum, 444  
 Cosmetics, 151, 158, 203, 276, 294-6, 302-3, 353<sub>n</sub>, 405, 449  
 Costs, chemical, 12, 14, 20  
 Cotton, 19, 115, 320, 334-5, 351, 379; linters, 40, 360, 386-7, 547  
 Cottonseed hulls, 431, 545; cellulose, 386-7, furfural, 350, 544-5; xylose, 423  
     meal, 318  
     oil, 320, 544  
 Cottrell precipitators, 107  
 Coumaric anhydride, 305<sub>n</sub>  
 Coumarin, 305-6, 444, 457-8, 529  
 Coumarone, 357; resins, 210, 447  
 Council on Pharmacy & Chemistry, American Medical Association, 246, 251<sub>n</sub>, 284  
 Coya Norte Mine (nitrate), 315  
 Cracking, petroleum, 132-5, 194-7, 391-4, 399, 404  
 Cream of tartar, 444, 457-8, 477  
 Creosote oil, 207, 212-4, 444, 457-8, 484  
 Cresol, 208, 217, 219, 222, 254, 398, 444, 447; U. S. P., 218, 457-8  
     *m*-Cresol, 217<sub>n</sub>, 299  
     *o*-Cresol, 217<sub>n</sub>, 357, 457-8  
     *p*-Cresol, 217<sub>n</sub>, 357; methyl ether, 298  
 Cresson medal, Elliott, 268<sub>n</sub>  
 Cresylic acid, 13<sub>n</sub>, 217-8, 441, 451-2, 477  
 Crotilidine aniline, 410  
 Crotonaldehyde, 183, 270, 444, 477  
 Cryolite, 144, 341, 444, 477  
 Crystal violet, 238-9  
 Cuba, molasses, 161-2  
 Culture media, 288  
 Cumene, 444, 478  
 Cumidine, 444  
 Cuprammonium rayon, 377, 380, 382, 384-5, 547  
 Cupric; Cuprous; *see* Copper  
 Curaçao, phosphates, 100  
 Cutworms, control of, 341  
 Cyanamide, *see* Calcium cyanamide process, *see* Nitrogen fixation  
 Cyanide process (gold, silver), 43, 89  
 Cyanides, 444, 478, 515  
 Cyanogas, 43  
 Cyanogen chloride, 342  
 Cyclohexane, 398  
 Cylinders, for gases, 27, 125  
 Cymene, 299, 444, 478; *p*-, 201  
 Cyprus, pyrites, 82  
 Czechoslovakia, 15; chemical industry, 58-59  
 Dalhousie University, 39<sub>n</sub>  
 Dammar gum, 355  
 Damon Mound, sulfur, 74, 76  
 Dead oil, *see* Creosote oil  
 Dead Sea, bromine, 262  
 Death Valley, borax, 145, 272  
 Decahydronaphthalene, 200  
 Degreasers, 200  
 Dehairing agents, 422  
 Dehydration, of dyes, 212  
 Dehydrogenation, of alcohols, 201  
 Dehydrothiotoluidine, 444  
 Dekalin, 200  
 Delco Light, 397  
 Denaturants, *see* Alcohol, denatured; Methyl alcohol  
 Denison University, 399  
 Denmark, cryolite, 144; sodium fluosilicate, 342  
 Dentifrices, 254, 295, 303  
 Deodorants, 289<sub>n</sub>  
 Department stores *vs.* drugstores, 275  
 Derris root, 343  
 Detergents, 6, 96, 104<sub>n</sub>, 356, 422; *see also* Cleansers; Soap  
 Detonators, 39, 228<sub>n</sub>  
 Dextrin, 444  
 Dextrose, 423, 444  
 Diacetone alcohol, 191  
 Diacetylmorphine, 282-3  
 Diagnostics, 250, 288  
 Diamines, 444  
     2, 4-Diaminophenol, 122  
     Diaminostilbene, 444  
     Diamyl phthalate, 297  
     Dianisidine, 444, 478  
     Diaphragm chlorine cell, 114, 119  
     Diao brilliant green 3G, 240  
     2, 7-Dibromo-4-hydroxymercurifluorescein, disodium, 250  
     Dibutyl phthalate, 190, 297, 529  
     Dicalcium phosphate, 516, 518  
     Dichloramine-T, 247  
     Dichloroaniline, 221  
     Dichlorobenzene, *o*-, 200; *p*-, 200, 210, 222, 457-8, 529  
     Dichlorodifluoromethane, 425  
     Dichloroethyl ether, 198  
     Dichloroethylene, 425  
     Dichloromethane, 425  
     Dichlorophenol, 224  
     Dichlorophthalic acid, 441  
     Dietetics, 422  
     Diethanolamine, 198

- Diethyl phthalate, 529  
 selenium, 399  
 sulfate, 444, 478  
 Diethylaniline, 233  
 Diethylbarbituric acid, 246-8, 441, 468  
 Diethylene glycol, 198; monoethyl ether, 198  
 Digitalis, 287-8  
 Dihydroxynaphthalene, 444, 478  
 Dimethyl sulfate, 444, 478  
 Dimethylamine, 410, 457-8  
 Dimethylaminophenol, 444  
 Dimethylaniline, 233, 444, 457-8, 478, 529, 538  
 Dimethylphenylbenzylammonium hydroxide, 444  
 Dimethylphenylenediamine, 444  
 3, 7-Dimethylxanthine, 286-7  
 Dinitrobenzene, 444, 457-8, 530  
 Dinitrochlorobenzene, 444, 530  
 Dinitronaphthalene, 444  
 Dinitrophenol, 444, 457-8  
 Dinitrotoluene, 444, 530  
 Dioxane, 198  
 Diphenyl, 223  
 Diphenylamine, 399, 444, 457-8, 478, 536  
 Diphenylguanidine, 410-11, 457-8, 530  
 Diphenyloxide, 121, 222-3, 444, 530, 535  
 Diplodia, control of, 343  
 Dipyrindyl compounds, 323  
 Direct black EW, 530  
 blue 2B, 530  
 brown 3GO, 229  
 Discrella, 385<sub>n</sub>  
 Diseases, chemotherapy, 248-9  
 Disinfectants, 158, 192, 200<sub>n</sub>, 207, 212, 217, 222, 254, 289<sub>n</sub>, 344, 356; see 1, 38, 332, 343  
 Disodium phosphate, 96, 101-2, 463-4, 516, 518  
 Distillation, petroleum, 391<sub>n</sub>, 393-4; wood, *see* Wood chemicals  
 Distilled Spirits Code Authority, 164<sub>n</sub>  
 Distilled Spirits Institute, 164<sub>n</sub>  
 Di-*o*-tolylguanidine, 411, 530  
*p*-Ditolylthiourea, 410  
 Diuretics, 250, 286  
 Doctor solution, 391<sub>n</sub>  
 Dodson's Livertone, 247<sub>n</sub>  
 Dolomite, 421<sub>n</sub>  
 "Double superphosphate," 105<sub>n</sub>  
 Dover's powder, 275  
 Dow and Magnesium (Dow Chemical Co.), 140<sub>n</sub>  
 Dowmetal, 140  
 Dowtherm, 223  
 Dressings, 449  
 "Dritomic" sulfur, 341  
 Drug & Chemical Club (Druachem), N. Y., 26, 290<sub>n</sub>, 430, 431<sub>n</sub>  
*Drug & Chemical Markets*, 23, 27, 164, 437, 439, 502  
 "Drug manufacturer," 274<sub>n</sub>  
*Drug Markets*, 439  
 Drug products, 203, 248, 274-93, 449  
 Drug trade, 27, 203, 216, 237<sub>n</sub>, 253, 294, 342<sub>n</sub>, 424, 430, 437  
 Drugs, 11, 94<sub>n</sub>, 208, 443, 467-501; addiction, 247, 281; assay, 250, 275-6, 434; crude, 298, 303-4, 540; grinding, 449; *see also* Medicinals; Pharmaceuticals  
*Drugs, Oils & Paints*, 373  
 Drugs War Service Committee, 154<sub>n</sub>  
 Drugstores, 274-8  
 Drums, 27, 94, 356  
 Drury College, 189<sub>n</sub>  
 Dry cleaning, 121, 200, 343, 403, 422  
 Dry Color Manufacturers' Association, 373  
 "Dry ice," 425-6  
 Drying oils, for paints, 198, 357, 363-4, 365<sub>n</sub>, 366; *see also* Linseed oil; Tung oil; etc.  
 Drysalter's Club, 26  
 Duco, 36, 38, 352, 359  
 Duke University, 434  
 Dulcite, 444  
 Dulesco, 385<sub>n</sub>  
 Duplate, 420  
 Duracel Fibre, 386  
 Durez, 349  
 Dutch East Indies, quinine, 284  
 Dutch Guiana, bauxite, 131  
 Dyeing, 6, 96, 131, 237, 343, 419<sub>n</sub>; materials, 444, 478, 497  
 Dyes, 11, 14, 20, 35, 58, 67, 135, 152, 155, 165, 171, 266, 397, 403, 503; azo, 222, 228, 231, 238; cartels & trusts, 51-52, 56<sub>n</sub>, 57-60; coal-tar, 3, 6, 34, 36, 38, 45, 55, 59, 61<sub>n</sub>, 94<sub>n</sub>, 104<sub>n</sub>, 127, 184, 198, 207-8, 223, 227-42, 245-8, 250, 252-3, 343, 358, 425<sub>n</sub>, 443, 470, 472, 497, 526, 538-9; extracts, 478, 497; intermediates, 134, 221, 224, 228, 228<sub>n</sub>, 230<sub>n</sub>, 231, 233, 238; medicinal, 253<sub>n</sub>, 290; natural, 6, 449; sulfur, 131, 229, 233, 514; vat, 131, 134, 208, 219-21, 228, 230<sub>n</sub>, 231, 237  
 Dynamite, 39, 197, 203, 444

- Earthenware, 358  
 Earths, 443-4  
 Earwigs, control of, 341  
 East Indies, phosphate, 106n  
 Ebert prize, 288n, 437  
 Ecgonine, 444  
 Economic Council, 438  
 Economics, chemical, 433-4  
 Edgewood Arsenal, 266, 439  
 Edison medal, 268n  
 Education, chemical, 433-5, 437-8  
*Edward Mallinckrodt: A Memoir*  
 (Stout), 258n  
 Eighteenth Amendment, 160  
 Elastomers, 348  
 Electric furnace, 41, 89, 96, 104-6, 131,  
 319, 420  
 Electrical equipment, 6, 339, 371  
 Electrochemical Society, 39n  
 Electrochemicals, 58-59, 94n, 122, 433,  
 514  
 Electrochemistry, 122n, 435  
 Electrodes, 42, 223  
 Electrolysis, 39, 130-31, 140, 143, 202,  
 222, 336, 369-70; *see also* Alkalies  
 Electroplating, 141, 413  
 Elektrons, 141  
 Elements, 399-400, 443  
 Emery, 444  
 Emollients, 203  
 Emulsifiers, 422  
 Enamels, 138, 294, 353n, 357, 374n, 480  
*Encyclopedia Britannica*, 252n  
*Encyclopedia of Superstition*, 11n  
 Engineering & Industrial Research Di-  
 vision, National Research Council,  
 432  
 Endowments & gifts, chemical, 434-5,  
 437  
 Engines, 134; cooling agents, 197;  
 knocking, 397-8, 400-401; *see also*  
 Automobile industry; Fuels  
 England, 15; acetone, 184; alcohol,  
 199; alkalies, 111; Bergius proc-  
 ess, 395; bromine, 262; cartels, 50,  
 55-58; casein, 354; chemical in-  
 dustry & trade, 10n, 13, 18, 31, 50,  
 55-59, 61, 507-8; coal-tar chemi-  
 cals, 31, 208, 212, 218; dyes, 51,  
 56n, 59, 61n, 171; ephedrine, 284;  
 glycerin, 203; magnesium, 271; ni-  
 trogen, 91n, 311-3; phenol, 214,  
 216; phosphate, 100-101; rayon,  
 6n, 376-8, 382; rubber, 409; sul-  
 furic acid, 18, 26, 71; trichloro-  
 ethylene, 199; Weizmann process,  
 190  
 Entomology Bureau, 342, 344n  
*Ephedra equisetina*, 283n  
*Ephedra sinica*, 283  
*Ephedra vulgaris*, 283n  
 Ephedrine, 283-4, 287, 540  
 Ephetonine, 540  
 Epinephrine, 540  
 Epsom salt, *see* Magnesium sulfate  
 Ergot, 444  
 Essential oils, 296, 298, 298n, 301,  
 303-4  
 Ester gum, 355, 357, 359  
 Esters, 158, 271, 444, 535  
 Estonia, 15  
 Ethane, 195, 405, 425  
 Ethanol, *see* Alcohol  
 Ethanolamine, 198, 422  
 Ether, 198, 270, 398, 478, 530  
 Ethers, 444, 478, 535  
 Ethyl abietate, 201  
     acetate, 158, 178-9, 181, 188, 200,  
     201n, 398, 444, 457-8, 478, 495,  
     525, 530  
     bromide, 400, 530  
     cellulose, 121  
     chaulmoograte, 287, 540  
     chloride, 121, 166n, 270, 398, 402,  
     425, 444, 457-8, 478, 530  
     chloroacetate, 342  
     chlorocarbonate, 200, 478  
     ether, *see* Ether  
     lactate, 200-201  
     maleate, 297  
     myristate, 297  
     oxybutyrate, 201  
     ricinoleate, 297  
     vanillin, 306  
 "Ethyl" gasoline, 396, 401-3  
 Ethylhydrocupreine, 444  
 Ethylisopropylbarbituric acid, calcium  
 salt, 248  
 Ethylmercurithiosalicylic acid, sodium  
 salt, 251  
 Ethyl-3-E, 261  
 Ethyl-*m*-toluenesulfonamide, 221  
 Ethyl-*p*-toluenesulfonamide, 221  
 Ethylene, 121, 127, 195-6, 199, 261, 269,  
 429  
     bromide, *see* Ethylene dibromide  
     chlorobromide, 261  
     chlorohydrin, 121, 196, 216n, 444,  
     457-8, 478-9  
     compounds, 196  
     dibromide, 121, 260-61, 263-5, 401,  
     457-8, 479  
     dichloride, 196, 199, 333, 410, 444,  
     479

- Ethylene, glycol, 5, 41, 86, 121, 123, 127, 163, 166, 195-7, 203, 216<sub>n</sub>, 358, 429, 444, 457-8, 479; ethers, 122, 198; monoacetate, 445, 480; monoethyl ether, 196-8  
oxide, 198, 332, 343, 444, 479  
Etta Mine (spodumene), 271  
Eucalyptol, 444, 479  
Eucalyptus, 299  
Europe, cartels & trusts, 48-63  
Explosives, 36, 38-39, 46, 53, 55-56, 58, 93, 94<sub>n</sub>, 121<sub>n</sub>, 128, 166, 207, 228<sub>n</sub>, 359, 444-5, 449, 450<sub>n</sub>, 510, 514-5  
Exports, associations, 13, 60; chemical, 10<sub>n</sub>, 12, 12<sub>n</sub>, 18-19, 495-501  
Fabrics, coated, 6, 39, 348, 351, 353, 412, 417; *see also* Textiles  
Fabrikoid, 38, 417  
*Farm Chemurgic* (Hale), 215<sub>n</sub>  
*Farm Products in Industry* (Rommel), 387  
*Farmward March* (Hale), 215<sub>n</sub>  
Fast red, 229  
Fats, extraction, 545-6  
Fatty acids, 98<sub>n</sub>, 156, 429  
Federal Narcotics Control Board, 281-3  
Federal Trade Commission, 23, 27, 32, 36, 79<sub>n</sub>, 103, 124<sub>n</sub>, 246, 277-8, 291, 344, 356, 383, 437, 539, 542  
Feldspar, 421, 444  
Fellowships & scholarships, 252, 267, 288, 343, 356, 434  
Fenestra, 353  
Fermentation process (acetone-butanol), 88, 93, 173, 176, 184, 188-91; (alcohol), 160, 426; (citric acid), 269  
Fernbach process (acetone-butanol), 190  
Ferric chloride, 121, 221, 444, 457-8, 479  
Ferrite process (iron oxides), 372  
Ferrolloys, 5, 41-42, 444, 497  
Ferroluminum-silicon, 444  
-vanadium, 444  
Ferroboron, 444  
Ferrocerium, 444  
Ferrochrome, 444  
Ferromanganese, 105, 444, 479, 497  
-vanadium, 444  
Ferromolybdenum, 444  
Ferrophosphorus, 198, 325, 444, 479, 518  
Ferrosilicon, 444, 479  
-aluminum, 444  
-aluminum-vanadium, 445  
-vanadium, 445  
Ferrotitanium, 445  
Ferrotingsten, 445, 497  
Ferrouanium, 445  
Ferrous chloride, 221  
selenide, 399  
sulfate (copperas), 367-8, 444-5, 457-8, 479  
sulfide, 479  
Ferrovanadium, 445, 479, 497  
Ferrozirconium, 445  
Fertilizers, 11, 38, 43-44, 104<sub>n</sub>, 281, 311-31, 430, 433, 449, 450<sub>n</sub>, 479, 498, 502, 541; chemicals for, 68, 72, 85, 92, 94<sub>n</sub>, 100-102, 105-7, 510, 514-5, 518; code, 542; European, 53, 56, 58-59, 171, 234; industry, 28, 33, 54, 97-101, 106, 345, 542; *see also* Superphosphate  
Fibers, polymerized, 348; synthetic, 6, 19, 40, 40<sub>n</sub>, 417; *see also* Rayon  
Fillers, 136<sub>n</sub>  
Film, 6, 38, 68, 102, 122, 178, 182, 223, 351, 382, 510  
"Fine chemical maker," 274<sub>n</sub>  
Fine chemicals, 27, 35, 60, 94<sub>n</sub>, 107<sub>n</sub>, 127, 166, 182<sub>n</sub>, 245-73, 289, 291, 503, 514  
Finishes, *see* Coatings  
Finland, pine tar, 414  
Fire extinguishers, 199, 426, 426<sub>n</sub>  
Fireproofing, 96, 223  
Fireworks, 449  
Fish oils, 373  
scrap, 328  
Fixed Nitrogen Research Laboratory, 87, 88<sub>n</sub>, 90, 438  
Flares, 140  
Flashlights, 42  
Flavoring Extract Manufacturers' Association, 153<sub>n</sub>, 154  
Flavoring extracts, 192, 444-5  
Flavors, 294-307; coal-tar, 445, 479, 526  
Flies, control of, 343  
Flit, 343  
Floor coverings, enamels, 357; pigments, 368  
Floor tiles, composition, 210  
Floraid, 317  
Florida, insecticides, 337; mint, 298; phosphate rock, 97-99, 102<sub>n</sub>, 107<sub>n</sub>; tung oil, 364<sub>n</sub>, 365-6  
Florida Agricultural Experiment Station, 366-7  
Flotation, mineral, 97-98, 100<sub>n</sub>, 211-2, 217, 339, 356, 370-71, 414  
Flour, self-raising, 103

- Flückiger medal, 288*n*  
 Fluorene, 445, 467  
 Fluorides, 102, 341  
 Fluorine, 107, 341, 398*n*  
 Fluorspar, 144, 420, 445, 479  
 Fluosilicates, 341  
 Fluosilicic acid, 341  
 Fluxes, 144, 480  
 Food & Drug Administration, 137*n*, 231  
 Food, Drug & Insecticide Administration, 118, 270, 281  
 Food & Drugs Act, 279-80, 304, 338  
 Food industry, 46, 106*n*, 230*n*, 231, 280, 304-5, 352, 422-5, 514, 548  
 Fordney-McCumber Tariff (1922), 3, 13-14, 61-62, 218, 239, 268-9, 295-6, 339  
 Foreign & Domestic Commerce Bureau, 10*n*, 11-12, 313*n*  
 Forest Products Laboratory, 418, 419*n*  
 Formaldehyde, 193, 215, 254, 343, 349*n*, 392*n*, 412, 445, 457-8, 480, 498, 530; plastics, 44, 184, 348-9, 354, 544  
 Formic acid, 349*n*, 441, 451-2, 468; esters, 342  
 Formosa, camphor, 299  
 Fortune, 140  
 Four Founders Engineering Society, 397*n*  
 France, 15; alcohol, 199; Bergius process, 395; bromine, 262-3; chemical industry & trade, 12*n*, 13, 13*n*, 18, 18*n*, 59, 61; chemical mergers, 58-59; dyes, 56*n*, 59-60; fertilizer, 106; furfural, 349*n*; glycerin, 203; methanol, 170-71; nitrogen, 313; perfumes, 297; phosphate, 100-101; potash, 12, 54, 322-3, 326; sulfuric acid, 18; tariff, 61*n*  
 Franklin Institute, 39*n*; medal, 397*n*, 402*n*  
 Franklin & Marshall College, 371*n*  
 Freez Foil, 166  
 French chalk, 445  
 French process (zinc oxide), 369-70  
 Freon, 398*n*, 425  
 Friedel-Crafts reaction, 219-20, 299  
 Frood Mine (nickel), 340  
 Frozen foods, 425  
 Fructose, 423  
 Fruit, extracts, 302; jellies, 424, 434  
 Fruits, arsenic effect, 338  
 Fuels, 5, 171, 200; alcohol in, 152, 166; benzene in, 209-10, 212-4, 401; coal tar as, 215, 218; *see also* Gases; Gasoline  
 Fuller's earth, 394, 421, 445  
 Fulminates, 445  
 Fumigants, 43, 89, 200, 332-3, 342  
*Fundamentals of Organic Chemistry* (Lewis), 419*n*  
 Fungicides, 216*n*, 323, 338, 345  
 Fungus diseases, cost, 333  
 Furan, 350  
 Furfural, 219*n*, 350, 350*n*, 457-8; resins, 349, 349*n*, 544-5  
 Furfuryl acetate, 297  
 Furnaces, 101*n*, 128, 131, 369; *see also* Blast furnace; Electric furnace  
 Fusarium, control of, 343  
 Fusel oil, 158, 445, 480  
  
**G** salt, 457-8  
 Galactose, 445  
 Galalith, 445  
 Galena, 371  
 Galenicals, 274  
 Gall bladder, X-ray, 288  
 Gallic acid, 441, 468, 530  
*Gamble's Yearbook*, 356  
 Gas black, 442  
 Gases, 42, 81, 89, 138, 190, 439; compressed, 27, 449-50; hydrocarbon, 193-5, 199, 209-10, 212*n*, 269, 405-6; *see also* Coal gas; Natural gas; Water gas  
 Gasoline, 4, 42, 53, 121, 134, 158, 166, 191, 195*n*, 260, 261*n*, 263, 391-8, 401-6, 410, 415  
 Gasworks, by-products, 67, 85, 515  
 Gelatin, 424, 434, 449  
 Geneva Economic Conference, 18, 60-62  
 Geological Society of America, 421*n*  
 Geological Survey, 325, 325*n*  
 Georgia, barytes, 136; bauxite, 44, 132; calcium arsenate, 335-7; glass, 421; kaolin, 421; rayon, 381  
 Georgia School of Technology, 421  
 Geraniol, 302, 445, 471  
 German Bromine Convention, 263  
 German Manufacturers' Association, 60  
 German silver, 447  
 Germanin, 249  
 Germany, 15; acetone, 184; alcohol, 166, 199; barium compounds, 138; barytes, 136; Bergius process, 53, 395; bromine, 263-4; butyl acetate, 201; camphor, 300; cartels, 48-55, 58-59; chemical industry & trade, 12*n*, 13, 13*n*, 18, 18*n*, 31, 48-55,

58-62, 171<sub>n</sub>; chlorates, 130; coal-tar chemicals, 53, 200, 207-8; dyes, 51-52, 56<sub>n</sub>, 58-60, 235<sub>n</sub>; electrochemicals, 59; ephedrine, 284; fertilizers, 52-53, 106, 234, 316-7;  
 Germany, furfural, 349<sub>n</sub>; magnesium chemicals, 139; medicinals, 245-7, 249<sub>n</sub>; methanol, 11, 169, 171-2, 174-5, 177, 179, 181; motor fuels, 212; nitrogen, 31, 52-53, 91-93, 312-3; patents, 230<sub>n</sub>, 236, 239-41, 246-7, 254, 411; phosphate rock, 100; phosphoric acid, 108-9; phthalic anhydride, 218; potash, 12, 50-52, 55, 58, 263, 316, 322-3, 324<sub>n</sub>, 326, 507; potassium carbonate, chloride, hydroxide, 120, 121<sub>n</sub>, 131; rayon, 6<sub>n</sub>, 380; sulfuric acid, 18, 31; trichloroethylene, 199  
 Germicides, 142, 251, 288, 289<sub>n</sub>  
 Gibberella, control of, 343  
 Gibbs medal, 193<sub>n</sub>, 252<sub>n</sub>, 393<sub>n</sub>, 399<sub>n</sub>, 402<sub>n</sub>  
 Glass, 5, 29, 58, 111, 127, 138, 144, 300, 320, 337, 358, 420-21, 480, 502, 521, 548  
 Glauber's salt, 128-9, 448, 463-4, 491, 522  
 Glazes, 480  
 Gloss oil, 355  
 Gluconic acid, 423  
 Glucose, 423  
 Glue, 59, 434, 449  
 Glycerides, 98<sub>n</sub>  
 Glycerin, 39<sub>n</sub>, 122, 163, 166, 197-8, 203, 208, 355, 358, 358<sub>n</sub>, 445, 457-8, 480, 498  
 Glycerin Producers' Association, 203  
 Glycerophosphoric acid, 441, 468  
 Glycols, 445; *see also* Ethylene glycol  
 Glyptal resins, 207, 219, 358  
 Goiter, iodine for, 266-7  
 Gold, compounds, 445; recovery, 43, 89  
 Government *vs.* business, 7-9  
*Graf Zeppelin*, 195<sub>n</sub>  
 Grande Écaille Dome, sulfur, 74  
 Graphite, 445, 486, 499  
 Grasselli medal, 420  
 Grasshoppers, control of, 341  
 Greases, 156, 157<sub>n</sub>, 426<sub>n</sub>, 449  
 Great Britain, *see* England  
 Greece, 15; tariff, 61<sub>n</sub>  
 Greenland, cryolite, 144  
 Greensands, potash, 323  
 Grinnell College, 419<sub>n</sub>  
 Guaiacol, 445, 480; carbonate, 255, 445  
 Guanidine, 43, 410-11

Guano, 100  
 Gulfpride oils, 134  
 Gums & resins, natural, 355, 357-8, 360; *see also* Plastics  
 Guncotton, 188  
 Gunpowder, *see* Black powder  
 Gypsum, 31, 106<sub>n</sub>, 421, 445  
 Gypsy moth, control of, 337  
 "Gyro" cracking process, 394  
  
**H acid**, 451-2, 530  
 Haber process (ammonia), 86, 91, 91<sub>n</sub>, 170, 318, 320  
 Haiti, logwood, 538  
 Halides, benzene, 535-6  
 Halowax, 222-3  
 Hamburg medal, 288<sub>n</sub>  
*Handbook of Chemistry & Physics*, 266<sub>n</sub>  
 Hard salts, 483  
 Harrison Narcotic Act, 282-3  
 Harvard University, 252, 403<sub>n</sub>, 434, 438<sub>n</sub>, 539  
 Hawaii University, 287  
 Hawley-Smoot Tariff (1930), 317<sub>n</sub>, 338, 441-8  
 Heart stimulants, 288  
 Heat-exchange agents, 121, 223  
 Heavy chemicals, 10-11, 18, 33, 37, 44, 46, 60, 67, 91, 94<sub>n</sub>, 101, 102<sub>n</sub>, 112<sub>n</sub>, 127, 144, 259, 345, 503, 514, 548; European, 55, 58  
 Heavy spar, 136<sub>n</sub>  
 Hecter, 398  
 Heliotropin, 445, 471  
 Helium, 195  
 Hemlock, 418  
 Hemp, 386  
 Heroine, 282-3  
 Hevea tree, 409  
 Hexahydrophenol, 200, 215  
 Hexalin, 200, 215  
 Hexamethylenetetramine, 271, 410, 445, 457-8, 480, 530  
 Hexyl alcohol, 193, 441  
 n-Hexyl-2, 4-dihydroxybenzene, 251  
 Hexylresorcinol, 245, 251  
 History of Science Society, 386<sub>n</sub>  
 Holland, American holdings, 324; Bergius process, 395; molasses, 161; nitrogen, 313; phosphate rock, 100; quinine, 284-6; rayon, 380-81; rubber, 409<sub>n</sub>; sodium fluosilicate, 342; theobromine, 286  
 Hormones, 275, 436  
 Hospitals, chemical research, 252  
 Hoskins Mound, sulfur, 74-76

- Household chemicals, 40*n*, 117*n*, 118  
*Household Chemistry* (Goodell), 233*n*  
Hungary, chemical plants, 59  
Hydraulic brake fluids, 191  
Hydraulic presses, for oils, 545-6  
Hydrocarbons, oil & gas, 128, 133, 185*n*, 191-5, 198-9, 209-10, 212*n*, 269, 392, 392*n*, 396, 398, 405-6, 425  
Hydrochloric acid, 101*n*, 121-3, 128, 221, 377, 441, 451-2, 468, 548  
Hydrocyanic acid, 43, 88-89, 342  
Hydroelectric power, 41, 43*n*, 124, 132, 319-21  
Hydrofluoric acid, 441, 468  
Hydrogen, 87-89, 91, 93, 114, 121, 170-71, 176-7, 190, 194, 395, 535  
    cyanide, *see* Hydrocyanic acid  
    peroxide, 124, 136*n*, 137*n*, 398, 417, 445, 457-8, 480, 498  
    sulfide, 77, 80-81, 131, 514*n*  
Hydrogenation, 53, 171*n*, 193, 200, 298*n*, 395-6, 404-5  
Hydrolysis, 191, 216, 350*n*, 367, 534-6  
Hydroquinone, 531  
Hydroxyalkylamines, 445  
 $\alpha$ -Hydroxybutyraldehyde, 412  
Hydroxymercurochlorophenol, 323, 343  
Hydroxyphenylarsinic acid, 441  
Hygiene, industrial, 214  
Hygienic Laboratory, 240, 250, 539  
Hyosine hydrobromide, 287*n*  
Hypnotics, 247*n*  
Hypochlorites, 394  
Hypophosphites, 104  
Ice cream, 305, 425  
Idaho, phosphate rock, 102  
Illinois, fluorspar, 144  
Illinois University, 212, 252, 259*n*, 279*n*, 288  
Ilmenite, 367-8  
Imports, chemical, 10*n*, 15*n*, 19, 467-94  
Inda, 354  
Indanthrenes, 219  
Indene resins, 210, 447  
India, chromite, 143; ephedrine, 284; ilmenite, 368  
Indian Ocean islands, phosphates, 100-101  
Indian red, 474  
Indiana, mint, 298  
Indiana University, 90, 221, 283*n*  
Indicators, of kidney function, 250  
Indigo, 238, 445, 457-8, 480, 531  
Indigosols, 238  
Indoxyl compounds, 443  
Industrial Alcohol Institute, 13, 158  
Industrial Alcohol Manufacturers' Association, 153*n*, 158*n*, 166  
Industrial chemicals, 40*n*, 42, 58, 67-147, 166, 272, 408-28  
*Industrial & Engineering Chemistry*, 11, 90*n*, 154, 155*n*, 432, 549  
Influenza, remedies, 255, 265-6  
Ink, 232, 348, 357, 364, 414*n*, 449; powders, 445; removal, 122, 434  
Inosite, 445  
Insecticide Act, 281  
Insecticide & Disinfectant Manufacturers' Association, 218*n*, 222*n*, 344  
Insecticides, 40*n*, 43, 94*n*, 156, 157*n*, 200, 202, 216*n*, 254, 327, 332-47, 356, 430, 439, 514, 543  
Insects, losses from, 333  
Institute of American Meat Packers, 252  
Institute of Chemistry, 187, 433  
Institute of Paint & Varnish Research, 365*n*  
Institute of Paper Chemistry, 418  
Institute of Petroleum, 396*n*  
Insulation, electrical, 218, 223  
Interior Department, 8, 438  
Internal Revenue Bureau, 152-6, 159*n*  
International Acetylene Association, 11*n*  
International Chamber of Commerce, 62  
International Congress of Chemistry (1938), 11*n*, 141*n*, 399*n*  
*International Critical Tables*, 432  
International Economic Conference, League of Nations, 17  
International Nitrogen Cartel, 314  
International Opium Conference, 281  
International Union of Pure & Applied Chemistry, 252*n*, 432  
Interstate Commerce Commission, 125, 344  
Interstate Cottonseed Crushers' Association, 431*n*  
Inulin, 423, 445  
Invertase, 423  
Iodates, 266  
Iodides, 266  
Iodine, 12, 18*n*, 266-7, 275, 397, 424, 445, 457-8, 480  
Iodine Educational Bureau, 267  
Iodine Syndicate, 266-7  
Ionone, 302*n*, 445  
Iowa Academy, 419*n*; State College, 251; University, 369*n*  
Ipral, 248



- Iridium, 445  
Iron, 24, 108, 114-5, 135, 442, 446, 535;  
  *see also* Ferro; Ferrous  
  - ammonium oxalate, 445  
  blues, 497  
  carbonyl, 404  
  cyanide, 89  
  ferri(o) cyanide, 442  
  hydroxide, 445, 486  
  oxides, 80, 86-87, 93, 265, 372, 442,  
    445, 474, 486, 546  
  salts, 367  
  -sodium oxalate, 445  
  sulfide, 221, 445  
Iron & steel industry, 5, 19, 36, 46, 59,  
  61, 72, 85, 178, 180, 209-10, 213,  
  215, 218<sub>n</sub>, 395, 510, 518; *see also*  
  Iron; Steel  
Isoamyl alcohol, 192  
Isoamylethylbarbituric acid, 248  
Isobutane, 425  
Isobutyl alcohol, 194  
Isomenthol, 299  
Isooctane, 396  
Isopropyl acetate, 193  
  alcohol, 192-3, 195-6, 198, 453-4  
  chloride, 299  
  ether, 183  
  formate, 342  
Isopropyltoluene, 201  
Italy, 15; chemical industry & trade,  
  13, 13<sub>n</sub>, 18<sub>n</sub>, 58; citrus products,  
  269; mercury, 269; nitrogen, 313;  
  rayon, 6<sub>n</sub>, 381, 417; sulfur, 31, 51,  
  78-79; sulfuric acid, 18; Weiz-  
  mann process, 190  
Japan, 15; arsenic, 338; camphor, 31,  
  300, 455-6; chemical trade, 18<sub>n</sub>,  
  59; ephedrine, 284; iodine, 266;  
  menthol, 298-9; nitrogen, 90; phos-  
  phate, 101, 106<sub>n</sub>; pyroxylin prod-  
  ucts, 350; tariff, 61<sub>n</sub>  
Java, cinchona, 284-5; iodine, 266; ni-  
  trogen, 313  
Johns Hopkins University, 70<sub>n</sub>, 250,  
  283<sub>n</sub>, 288, 391, 403<sub>n</sub>, 421  
Jones-Parsons converter, 92<sub>n</sub>, 93  
*Journal of the American Chemical So-*  
*ciet*y, 252<sub>n</sub>, 549  
*Journal of the American Medical As-*  
*sociation*, 281<sub>n</sub>  
*Journal of the American Pharmaceuti-*  
*cal Association*, 279<sub>n</sub>, 437  
*Journal of Commerce*, 504  
*Journal of Organic Chemistry*, 252<sub>n</sub>  
*Journal of Pharmacology & Experi-*  
*mental Therapeutics*, 281<sub>n</sub>, 284<sub>n</sub>  
Justice Department, 9<sub>n</sub>, 159, 241, 285,  
  323, 538-9  
Jute, 386  
Kadox, 369  
Kainite, 481  
Kalirat (Ger.), 54-55  
Kanawha Valley, chemical plants, 29  
Kansas Agricultural College, 316  
Kansas University, 210<sub>n</sub>  
Kaolin, 421, 445  
Kapak, furfural from, 350  
Karolith, 354  
Katanga mines, copper, 340  
Kelp, iodine, 266, 424; furfural, 544  
Kentucky, fluorspar, 144; wood chemi-  
  cals, 174  
Keratol, 353  
Kerosene, 135, 156-7, 341, 397, 400, 405  
Ketones, 173, 201, 299<sub>n</sub>, 357, 391<sub>n</sub>  
Key Industry Act (Eng.), 184  
Kieserite, 481  
Kina Bureau (Holland), 284-6  
Kitchenwares, colors for, 374  
Knockknocker, 398  
Koch's acid, 531  
Kodapak, 353  
Kola nuts, 286<sub>n</sub>  
Koroseal, 413  
Kraft paper, 122, 128-9, 418  
Kryolith, 477  
Kyloid, 354  
Labeling, aromatics, 295; drugs, 276,  
  279-80; fabrics, 417  
Laboratories, industrial & university,  
  252, 275, 434-5  
Lacquer Institute, 360  
Lacquers, 4, 6, 36, 38-39, 40, 42<sub>n</sub>, 56,  
  58, 67, 96, 228<sub>n</sub>, 348, 351-3, 357-  
  60, 363-4, 366, 368, 374, 418, 424,  
  433; solvents, 158, 178, 184, 187-  
  91, 198, 200, 200<sub>n</sub>, 214  
Lactic acid, 441, 451-2, 468  
Lafayette College, 435<sub>n</sub>  
Lakes, 137<sub>n</sub>, 231, 373-4, 443, 481, 526,  
  532, 539  
Lampblack, 442, 449, 481, 496, 498  
Lard oil, 546  
Larvacide, 342  
Latex, 409, 412-3  
Latvia, 15  
Laudanum, 445  
Laundries, detergents, 144  
Laury furnace, 128

- Laussane University, 433  
 Lawyers' Club (N. Y.), 26  
 Lead, 82, 102, 220, 271, 334, 338, 370-72, 445; pigments, 37, 368, 370-71, 445-6, 481; poisoning, 401-3, 417  
   acetate, 445, 457-8, 481  
   arsenate, 333, 337-8, 344, 445, 459-60, 481, 498, 543  
   bromide, 260  
   carbonate, 368, 459-60, 481, 498; *see also* White lead  
   compounds, 481  
   nitrate, 445, 481  
   oxide, 260, 355, 400; *see also* Litharge; Red lead  
   resinate, 445, 481  
   suboxide, 371  
   sulfate, 481  
   -tin phosphate, 417  
   titanate, 367*n*  
   triethylbromide, 401  
 League of Nations, Economic Conference, 18, 60-62  
 Leather, 131, 166, 166*n*, 227, 359, 421-2, 502, 548; artificial, 39, 56, 158, 200, 214, 353  
 Leavening compounds, 104*n*, 105, 449; *see also* Baking powder  
 Leaves, medicinal, 247  
 Leblanc process (alkalies), 55, 58, 128  
 Leishmaniasis, remedies, 540  
 Lemon oil, 269  
 Leprosy, remedies, 287-8, 540  
 Lester Institute for Medical Research, Henry (Shanghai), 540  
 Lethane, 323, 343  
 Leuco compounds, 238, 443  
 Leunaspeter, 11, 53, 313, 317  
 Levulose, 423, 445  
 Light oil, 209-10, 212-4  
 Lignin, 387  
 Lime, 18, 112, 131, 199, 230*n*, 272, 325, 338*n*, 355, 367, 426, 481, 498, 548; chlorinated, *see* Bleaching powder; hydrated, 445, 481-2  
   acetate, *see* Calcium acetate  
   borate, 445  
   citrate, *see* Calcium citrate  
   nitrogen, *see* Calcium cyanamide  
 Lime-soda process (caustic), 520  
 Lime-soda softening process, 78*n*, 131  
 Linalool, 302  
 Liniments, 192, 275  
 Linoleum, 364, 369  
 Linseed oil, 198, 363-4, 371, 461-2  
 Lipstick, 294, 303  
 Liquors, 449; *see also* Alcohol  
 Litharge, 371, 445, 459-60, 482, 499, 546  
 Lithium, 271, 445  
 Lithopone, 28, 37, 53, 58-59, 136-7, 368-72, 445, 459-60, 482, 498, 524, 546  
 Logwood, 445, 538; extract, 459-60, 498  
 Lolustra, 385*n*  
 London purple, 445, 485  
 Long Island College of Medicine, 253*n*  
 Long Point Dome, sulfur, 74  
 Longstreth medal, 39*n*, 398*n*, 399  
 Louisiana, carbon black, 414-5; natural gas, 209, 415, 416*n*; rice wastes, 387; sugar, 422-3; sulfur, 74, 76  
 Lubricants, 4, 223, 350, 404-5, 422, 434; oil, 134, 222, 391  
 Lucite, 87  
 Lumarith, 351  
 Luminal, 248  
 Lupulin, 445  
 Lye, 118, 498, 521, 521*n*  
 Lysol, 254  
  
 Ma huang, 283-4, 540  
 Machine tools, alloys, 5  
 Madagascar, vanilla, 305  
 Magnesia, 131, 271, 290, 355*n*, 421*n*, 482  
 Magnesite, 139, 445, 482  
 Magnesium, 140-41, 445, 482; alloys, 138, 140-41, 445  
   arsenic compounds, 543  
   carbonate, 139, 445, 459-60, 482  
   chloride, 139, 264-5, 325, 445, 459-60, 482  
   compounds, 139, 498  
   hydroxide, 140, 265  
   oxide, 139, 265, 445-6, 459-60  
   oxychloride, 139  
   silicofluoride, 445, 483  
   sulfate (Epsom salt), 70, 139-40, 265, 275, 325, 445, 459-60, 483  
 Maine, electrolytic industry, 125  
 Maine University, 419*n*  
 "Majestic" baking powder, 424  
 Makatea Island, phosphates, 101  
 Malachite green, 231, 538-9  
 Malaria, remedies, 286  
 Mallinckrodt Chemical Laboratories, Edward, 434-5, 439  
 Malt sirup, 424  
*Man in the Chemical World* (Morrisson) 11*n*  
*Manchester Guardian*, 56

- Manganese, 445; alloys, 442  
   borate, 446, 483  
   chloride, 459-60  
   compounds, 446, 483  
   -copper, 445  
   dioxide, 349n, 459-60  
   linoleate, 446, 483  
   oxide, 355  
   resinate, 446, 483  
   sulfate, 446, 483  
 Mannheim furnace, 128  
 Mannitol (mannite), 39, 446  
 Mannose, 39n, 446  
 Manufacturing Chemists' Association,  
   10n, 11n, 23, 27, 44n, 60, 62, 153n,  
   154, 213, 437, 503, 549  
 Manure salts, 483  
 Maple Floor Manufacturers' Associa-  
   tion, 9  
 Marble, imitation, 349  
 Maryland University, 251n, 434  
 Masbrite board, 419  
 Mass production, of chemicals, 4, 19-  
   20, 32-33  
 Massachusetts Agricultural Experi-  
   ment Station, 317  
 Massachusetts Department of Health,  
   249  
 Massachusetts Department of Labor &  
   Industries, 213n  
 Massachusetts General Hospital, 213n  
 Massachusetts Institute of Technology,  
   70n, 122n, 199, 396, 400, 402n,  
   413n  
 Massage compounds, 192, 303  
 Matches, 130  
 Materia medica, 247, 280  
 Meat curing, 130, 316  
 Meat-packing industry, 85, 316, 422  
 Mechanical industries, chemicalization,  
   409  
 Medals, *see* Prizes & medals  
 Medical Economics, 253n  
 Medical schools, research, 251  
 "Medicinal chemical maker," 274n  
 Medicinals, 31, 40, 142, 151, 247, 253n,  
   257, 266, 272, 274n, 275, 290-91,  
   303, 430, 449; coal-tar, 3, 34, 45n,  
   59, 127, 207-8, 245-56, 443, 497,  
   527; *see also* Drugs; Pharmaceu-  
   ticals  
 Medicine, 251  
 Medicine, 540  
 Melezitose, 446  
 Melibiose, 446  
 Mellon Institute of Industrial Research,  
   68n, 90n, 158-9, 194, 252, 267, 288,  
   337, 343, 354, 422, 424  
*Mentha arvensis*, 298, 298n  
 Menthol, 255, 298-9, 302, 446, 459-60,  
   483  
 Menthol-Y, 299  
 Merchandising, *see* Selling  
 Mercuric chloride, 459-60, 483  
   oxide, 446  
 Mercurio Europeo, 269  
 Mercurochrome, 245, 250  
 Mercurous chloride, 267, 459-60, 483  
 Mercury, 220, 250, 267-9, 446, 459-60,  
   483, 494, 498; electrolytic cell, 114  
   acetate, 250  
   compounds, 249-50, 252, 267, 343  
   oxide, 483  
   preparations, 443, 483  
 Mergers, chemical & drug, 17, 31-47,  
   53, 55, 55n, 163-6, 180, 230-36,  
   257-8, 289-91, 302-3, 345, 372-3  
 Merthiolate, 251  
 Metal cleaners, 158, 200  
*Metallbörse*, 69  
 Metals, 19, 68, 170n, 289n, 510; alloys,  
   446; compounds, 34, 92, 170n; non-  
   ferrous, 46; organic compounds,  
   399; pigments, 499; rubber-coat-  
   ing, 413; soaps, 366  
 Metallurgy, 5-6, 68, 122n, 369n  
 Metalwares, 430  
 Metanilic acid, 441  
 Metaphen, 245, 251  
 Methacrylate resins, 87  
 Methane, 93, 170, 172, 176, 405  
 Methanol, *see* Methyl alcohol  
 6-Methoxy-8-(1-methyl-4-diethylami-  
   nobutyl)-quinoline, 286n  
 Methyl acetate, 181, 459-60  
   acetone, 459-60, 525  
   acetophenone, 297  
   alcohol, 11, 13n, 21, 46, 53, 87, 127,  
   155-6, 169-82, 184-5, 187, 190, 194,  
   199, 250, 392n, 429, 441, 453-4,  
   470, 495, 525  
   anthranilate, 446  
   Cellosolve, 198  
   chloride, 184, 425, 459-60  
   chloroacetate, 342  
   ethyl ketone, 201, 405, 446  
   methacrylate, 87  
   radical, 172, 178, 184  
   rubber, 413  
   salicylate, 42, 446, 531  
   selenium, 399  
   violet, 531

- Methylamines, 422  
 Methylantracene, 446, 467  
 Methylantraquinone, 220, 446, 483  
 Methyl-naphthalene, 446, 467  
 1-Methyl-2-(3-pyridyl)-pyrrolidine, 332  
 Methylation, 425<sub>n</sub>  
 Methylene blue, 127, 231, 238  
   green, 231  
 Mexico, arsenic, 338; vanillin, 305  
 Michigan, brine chemicals, 139; mint, 298; wood chemicals, 174, 181  
 Michigan University, 215<sub>n</sub>, 216<sub>n</sub>, 434, 539  
 Microorganisms, pathogenic, 248-9  
 Midol, 247<sub>n</sub>  
 Mildewproofing, 6  
 Milk of magnesia, 247<sub>n</sub>, 290  
 Milk Sugar Institute, 125<sub>n</sub>  
 Millinery trade, Cellophane in, 352  
 Milorganite, 318  
 Milwaukee, sewage disposal, 318  
 Mineral earth, 486  
   oil, 193; *see also* Petroleum  
   salts, 446, 484  
   spirits, 501  
*Mineral Industry*, 209<sub>n</sub>, 339<sub>n</sub>  
 Minerals, 137, 421, 424, 433; flotation, 97-98, 100<sub>n</sub>, 211-2, 217, 339, 356, 370-71, 414  
 Mines Bureau, 4<sub>n</sub>, 98, 143, 166<sub>n</sub>, 213<sub>n</sub>, 250<sub>n</sub>, 265<sub>n</sub>, 325, 325<sub>n</sub>, 326<sub>n</sub>, 393, 397, 403, 438  
*Mines Handbook*, 339<sub>n</sub>  
 Mining & Metallurgical Society of America, 78<sub>n</sub>  
 Minnesota University, 122<sub>n</sub>, 252<sub>n</sub>  
 Mint, & oil, 298-9  
 Mississippi, clays, 421; wood chemicals, 174  
 Mississippi Valley, chemical plants, 28  
 Missouri, barytes, 136-7, 367; drug-stores, 278; lead, 371; lime, 367  
 Missouri Grain Dealers & Millers Association, 104<sub>n</sub>  
 Missouri State Medical Association, 282<sub>n</sub>  
 Missouri University, 321<sub>n</sub>, 421  
 Mixed acid (sulfuric-nitric), 441, 449, 449<sub>n</sub>, 468  
 Modern Pioneer award, 39<sub>n</sub>, 141<sub>n</sub>, 193<sub>n</sub>, 252<sub>n</sub>, 369<sub>n</sub>, 413<sub>n</sub>  
 Moistureproofing, 6, 352  
 Molasses, 190<sub>n</sub>; alcohol, 160-63, 165, 203; bleach, 131; glycerin, 203; waste potash, 54, 323  
 Molding powder, 351  
 Molybdenum, 446  
 Monarch Cream baking powder, 424  
 Monopolies, foreign, 323; *see also* Cartels; Mergers; Trusts  
 Mont Cenis process (ammonia), 89  
 Mordants, 6, 449  
 Morocco, phosphate rock, 100  
 Morphine, 281<sub>n</sub>, 282, 287<sub>n</sub>, 446; sulfate, 446, 459-60  
 Mosquitoes, control of, 343  
 Motalin, 404  
 Mothproofing, 6, 343-4  
 Motor fuels, *see* Fuels  
 Moving picture industry, chemicals for, 5-7, 223, 351  
 Mucilages, *see* Adhesives  
 Mum, 290  
 Mundatechnical Society of America, 343  
 Munitions, 34, 91, 202, 322, *see also* Explosives  
 Muralart, 417  
 Muriatic acid, *see* Hydrochloric acid  
 Muscle Shoals, 44, 56, 86, 93, 104, 106, 132, 311, 318-22, 326  
 Musk, 298, 301, 301<sub>n</sub>, 446, 484  
   ambrette, ketone, xylene, 301  
 Mustard gas, 121<sub>n</sub>  
   oil, 302  
 Nail enamels, 294, 353<sub>n</sub>  
 Naphtha, 213-4, 405; solvent, 355, 459-60  
 Naphthalene, 121, 208, 213, 221-2, 446, 459-60, 484, 499, 530, 534  
 Naphthionic acid, 531  
 Naphthol,  $\alpha$ -, 230<sub>n</sub>, 231, 394, 446, 459-60, 484;  $\beta$ -, 207-8, 357, 446, 459-60, 484, 531; dyes, 222, 238  
   yellow S, 231  
 Naphthylamine, 446, 484;  $\alpha$ -, 459-60, 531;  $\beta$ -, 412, 459-60  
 Naphthylenediamine, 446, 484  
 Narcotic Drug Import & Export Control Act, 281  
 Narcotics, 281-3  
 National Academy of Sciences, 402<sub>n</sub>  
 National Association of Boards of Pharmacy, 435  
 National Association of Dyers & Cleaners, 344<sub>n</sub>  
 National Association of Manufacturers, 11<sub>n</sub>, 28, 39<sub>n</sub>, 43<sub>n</sub>, 44<sub>n</sub>, 413<sub>n</sub>  
 National Association of Purchasing Agents, 23-24, 502-3  
 National Association of Retail Druggists, 154, 278, 282<sub>n</sub>

- National Bureau of Casualty & Insurance Underwriters, 214  
 National Bureau of Economic Research, 46*n*  
*National Directory of Commodity Specifications*, 438  
 National Drug Trade Conference, 153, 280  
 National Fertilizer Association, 13, 62, 91, 97*n*, 317*n*, 320, 322, 322*n*, 326, 328, 542-3  
 National Industrial Conference Board, 43*n*  
 National Labor Board, 44*n*  
 National Oil, Paint & Varnish Association, 153*n*, 155*n*  
 National Paint, Varnish & Lacquer Association, 344*n*  
 National Prohibition Act, *see* Volstead Act  
 National Recovery Act (NRA), 329  
 National Research Council, 11*n*, 204*n*, 246, 251, 251*n*, 284*n*, 390, 402*n*, 432-4  
 National Research Council, Canada, 81  
 National Retail Dry Goods Association, 383, 419  
 National Safety Council, 213  
 National Varnish Manufacturers' Association, 373  
 National Wholesale Druggists' Association, 27, 153*n*, 154, 276-8, 280, 282*n*  
 National Wood Chemical Association, 172, 185  
 Natural gas, 29, 42, 74, 77*n*, 89, 93, 184, 185*n*, 192, 194-5, 209, 394, 405-6, 415-6, 426*n*, 429  
 Nauru Islands, phosphates, 101  
 Naval Proving Ground, 513  
 Naval stores, 18, 39-40, 201, 355-6, 431; *see also* Rosin; Turpentine  
 Naval Stores Act, 281  
 Naval Stores Advisory Committee, Bureau of Chemistry & Soils, 355*n*  
 Navy Department, 8, 339, 344*n*, 539  
 Nebraska, potash, 54, 323  
 Neosarsphenamine, 247, 249-50, 446, 531  
 Neonal, 248  
 Neonicotine, 332  
 Neoprene, 409  
 Neosynephrine, 540  
 Neozone, 412  
 Nevada, potash, 324; sodium sulfate, 128-9, 324; sulfur, 80  
 Nevada University, 143  
 New Caledonia, chromite, 143  
 New England, ammonia, 21; textile industry, 381  
 New Hampshire, rayon, 381  
 New Idria Mine (mercury), 268  
 New Jersey, potash, 323; wood chemicals, 181  
 New Jersey College of Agriculture, 316  
 New Jersey College of Pharmacy, 288, 424, 424*n*  
 New Jersey Department of Labor, 403  
 New Jersey War Finance Committee, 285*n*  
 New Mexico, potash, 322, 325-6; sodium sulfate, 128  
*New & Non-Official Remedies*, 251*n*  
 New York, mint, 298; wood chemicals, 174, 181  
 New York Academy of Sciences, 11*n*  
 New York City College, 26*n*, 299*n*  
 New York College of Pharmacy, 252, 253*n*, 290, 291*n*, 296  
 New York Pharmaceutical Conference, 277  
 New York State Board for Licensing Professional Engineers, 114*n*  
 New York University, 435  
*New York World*, 402  
 Nichols Chemical Building, 435  
 Nichols Foundation, 435  
 Nichols medal, 252*n*, 288*n*, 399*n*, 402*n*  
 Nickel, 93, 114-5, 142, 340, 446-7; alloys, 442, 446  
     carbonyl, 404  
     oxide, 398, 446, 484, 499  
     salt(s), 459-60, 499  
     sulfide process, (sulfur), 80  
 Nicotine, 332; sulfate, 449  
 Nigrosine, 531  
*Niobium*, 446  
 Niter cake, 101*n*, 128, 221, 446, 459-60, 490, 522  
 Nitrates, 515  
 Nitration, 40, 71, 360  
 Nitric acid, 31, 36, 39, 46, 85, 90-94, 101*n*, 123, 128, 328, 368, 418, 441, 449, 451-2, 515-6  
     oxide, 91  
 Nitro rayon, 377-8, 381-2, 384, 384*n*, 547  
 Nitroaniline, 446, *m*-, 484; *o*-, 221; *p*-, 221, 357, 459-60, 484, 531  
 Nitroanthraquinone, 446, 472  
 Nitrobenzaldehyde, 446  
 Nitrobenzene, 221, 223, 233, 446, 459-60, 531

- Nitrocellulose (pyroxylin), 40, 42*n*, 181, 351, 354, 358-60, 377, 381, 384, 459-60, 477; compounds, 488, 499; lacquers, 36, 40, 96, 187-8, 198, 200*n*, 214, 352*n*, 357-60, 363, 374; plastics, 348, 350-51; products, 46, 350, 353, 417, 447
- p*-Nitrochlorobenzene, 461-2
- Nitrodiphenyl, 223
- 4-Nitro-5-hydroxymercuri-*o*-cresol anhydride, 251
- Nitromannitol, 39
- Nitronaphthalene, 446
- Nitroparaffins, 190*n*
- Nitrophenol, 446
- Nitrophenylenediamine, 446
- Nitrophoska, 313, 317
- Nitrotoluene, 233, 446, 461-2, 531-2
- m*-Nitro-*p*-toluidine, 221
- Nitrotoluylenediamine, 446
- Nitrogen, 12, 18, 37, 53, 56, 106, 176, 433*n*, 434, 515*n*, 541; in fertilizers, 11, 44, 53, 58, 85, 105, 311, 479, 498; fixed, 29, 40, 85-93, 311-4, 318-22, 395, 450, 515; *see also* Ammonia; Nitric acid compounds, 311, 450 peroxide, 91*n*, 92
- Nitrosodimethylaniline, 446
- Nolan Act, 220
- Nonmetallic Minerals Experiment Station, Bureau of Mines, 325
- No-Nox gasoline, 134
- North Africa, phosphate rock, 99-100
- North Carolina, feldspar, 421; mint, 298; rayon, 29, 381
- North Carolina State College of Agriculture & Engineering, 421
- Northwest, paper, 418
- Northwestern University, 252, 320*n*, 433*n*
- Norway, nitrogen, 86, 90, 91*n*, 313; power plants, 41; pyrites, 82; titanium, 368; wood pulp, 386
- Notre Dame University, 211*n*
- Nova Scotia Institute, 39*n*
- Novocaine, *see* Procaine
- Nulomoline, 423
- Nutrition, 422
- Nyal drugs, 276
- Nylon, 87
- Oat hulls, cellulose, 387; furfural, 350, 350*n*, 544-5
- Oberlin College, 434
- Oberphos process (superphosphate), 318
- Ocean Island, phosphates, 101
- Ochers, 446, 484
- "Octane," 134
- Office Chérien des Phosphates, 100
- Ohio, brines, 265; rayon, 381
- Ohio State University, 313, 397, 397*n*, 399, 413*n*
- Ohio Wesleyan University, 419*n*
- Oil & Gas Journal*, 393
- "Oil of the Dutch chemists," 199*n*
- Oil of mirbane, 531
- Oil, Paint & Drug Reporter*, 155*n*, 263, 344, 434, 437
- Oilcloth, 357, 364
- Oils, 98*n*, 178*n*, 184, 198, 200, 296, 298, 298*n*, 301, 303-4, 356-7, 360, 363-75, 405, 422; sprays, 341, 343; vegetable, 521; *see also* Petroleum
- Ointments, 274
- Oiticia oil, 363
- Oklahoma, glass, gypsum, natural gas, 421
- Oklahoma University, 421
- Old Gulf, *see* Big Hill Dome
- Olefins, 193, 391*n*, 405
- Oleic acid, 98, 422, 441, 469, 495
- Oleoresins, 302
- Oleum, *see* Sulfuric acid
- Olive drab dyes, 238
- Olive oil, 287
- Onyx, imitation, 349
- Opax, 421
- Opium, 281-3, 446, 461-2, 485
- Opium Problem* (Terry & Pellens), 281*n*
- Optical glass, 138
- Orange, colors, 230*n*, 532, 539 mineral, 446, 485, 499 oil, 269
- Orchard Dome, sulfur, 74
- Oregon, sodium sulfate, 128
- Organic chemistry, 251-2
- Organic Compounds of Mercury* (Whitmore), 252*n*
- Organic Syntheses*, 252*n*
- Organic synthesis, 3, 29, 94*n*, 108-9, 112, 119*n*, 121, 123, 127, 131, 134-5, 151-256, 267, 280, 295-7, 332-3, 429, 433, 526-34, 535-7
- Osmium, 446
- Owens Lake, caustic soda, 118
- Oxalic acid, 377, 441, 451-2, 469, 548
- Oxidation, 156-7, 170*n*, 219, 265
- Oxides, metallic, 170*n*, 355, 355*n*
- Oxidizers, 130, 371, 424
- Oxyacetylene, 41
- Oxygen, 41, 92, 399, 499

- Pacific Coast, *see* West Coast  
 Packaging, 27, 274*n*, 275-6, 280, 344, 374, 425  
 Paint Manufacturers' Association of U. S., 365*n*, 373  
 Paint, Oil & Varnish Association, 211*n*  
 Paints & pigments, 5, 11, 33, 37, 53, 94*n*, 114*n*, 136, 136*n*, 155, 166, 182*n*, 187, 200*n*, 201, 221, 223, 228*n*, 232, 265, 299, 339, 345, 354, 357-8, 360, 363-9, 372-4, 412, 414*n*, 439, 449, 502, 510, 514  
 Palangana Dome, sulfur, 74, 76-77  
 Paleontological Society of America, 421*n*  
 Palladium, 446, 485  
 Palm oil, 414  
 Pamaquine, 286*n*  
 Panama, sugar, 166  
 Paperboard, 418-9  
 Paper & pulp, 19-20, 29, 45, 73, 81, 111, 112*n*, 113, 115, 119, 122, 124, 128-9, 135, 136*n*, 178, 201-2, 227, 352*n*, 386-7, 412, 418-9, 422, 431, 434, 502, 514, 521, 522, 548  
 Pape's Diapepsin, 247*n*  
 Para red, 301*n*, 532  
 Paracetaldehyde, 446, 485  
 Paraffin, 299, 352*n*  
 Paraformaldehyde, 446, 485, 532  
 Paraldehyde, 183, 270, 461-2  
 Paraplex, 358  
 Parasites, 249  
 Paris green, 333, 344, 446, 461-2, 485, 543*n*  
   white, 443, 494  
 Paris Peace Conference (1919), 301*n*, 439*n*  
 Parkerizing process, 108  
 Pastes, *see* Adhesives  
 Patent medicines, *see* Proprietary drugs  
 Patent Office, 142, 348, 411, 438  
 Patents, 11, 220; *see also* Germany, patents  
 Peach pits, carbon, 181  
 Peanut hulls, 545; xylose, 423  
 Pebeco tooth paste, 254  
 Pecans, 545  
 Pectin, 269, 424  
 Peking Union Medical College, 283-4, 540  
 Penicillium, 423  
 Pennsylvania, petroleum, 405; wood chemicals, 174, 181  
 Pennsylvania State College, 137*n*, 187, 252, 267, 433  
 Pennsylvania University, 283*n*, 284, 435*n*  
 Pent-acetate, 192  
 Pentanes, 121, 191-2, 199, 406, 454*n*  
 Pentasol, 192  
 Pentosans, 350, 544-5  
 Peppermint oil, 298, 461-2  
 Pepsodent tooth paste, 295  
 Perchloric acid, 122  
 Perfumery Show (1923), 296  
 Perfumery, Soap & Allied Industries, 296  
 Perfumes, 158, 192, 291, 294-305, 446, 449, 527; *see also* Aromatics  
 "Perfumopoeia," 296  
 Periclase, 446  
 Perilla oil, 363  
 Periodic table, 399-400  
 Perkin medal, 20*n*, 122*n*, 141*n*, 228, 324, 393*n*, 399*n*  
 Permian Basin, potash, 325-6  
 Persulfates, 417  
 Peru, nitrate, 312  
 Pervitin, 540  
 Pesticides, 332-47; *see also* Insecticides; Rodenticides  
 Petroleum, 18, 46, 80, 89, 98, 132-5, 171*n*, 191-7, 199, 210*n*, 218*n*, 265, 267, 325-6, 350, 390-407, 415, 416*n*, 425, 426*n*, 429, 514; refining, 6, 68, 70*n*, 111, 115, 118, 131, 222, 510, 521, 538; in sulfur domes, 74, 76-77  
 "Pharmaceutical manufacturer," 274*n*  
 Pharmaceuticals, 11, 17, 38, 59, 166, 207, 224, 232*n*, 245*n*, 247-8, 253, 254, 274-93, 296, 302, 324, 423, 434; *see also* Drugs; Medicinals  
 Pharmacology, 283-4, 434  
 Pharmacy, 251, 435  
 Phenacetin, 467  
 Phenobarbital, 248  
 Phenol, 5, 19, 121, 214-7, 219, 224, 245, 251, 332*n*, 405, 429, 446, 461-2, 485, 499, 532, 534-6; disinfectants, 207, 222; natural, 215, 217; plastics & resins, 207-8, 245, 348-51, 354, 357, 364, 544-5  
 Phenolphthalein, 446, 485, 532  
 Phenols, 216*n*, 254, 357  
 Phenolsulfonates, 255, 532  
 Phenolsulfonphthalein, 250  
 Phenyl selenium, 399  
 Phenylacetaldehyde, 446  
 Phenyl-azo-diaminopyridine, 290  
 Phenylethyl alcohol, 301*n*, 441  
   propionate, 298

- Phenylethylbarbituric acid, 248  
 Phenylglycine, 446, 485, 532  
 Phenylhydrazine, 122, 446  
 Phenylmercuric chloride & nitrate, 251  
 Phenyl-naphthylamine, 412, 446  
 Phenylenediamine, 446, 485; *p*-, 221, 461-2  
 Philadelphia, alum, 21  
 Philadelphia College of Pharmacy, 252, 267, 288*n*  
 Philippine Bureau of Science, 193*n*  
 Phospharsphenamine, 250  
 Phosphate rock, 18, 60, 96-107, 318, 461-2, 517, 518, 541  
 Phosphates, 96, 100-3, 105, 107-8, 319, 324-5, 433*n*, 446, 485; *see also* Superphosphate  
 Phosphazote, 319  
 Phosphomolybdic acid, 374  
 Phosphor copper, 109  
 Phosphoric acid, 89, 96, 96*n*, 102, 102*n*, 104-8, 319, 326, 441, 451-2, 469, 516, 518, 541  
 Phosphorus, 89, 96, 99*n*, 104-5, 109, 311, 318, 337, 446, 485, 518, 541; alloys, 446  
     chlorides, 10  
     compounds, 96-110  
     oxychloride, 109, 224, 446  
     pentoxide, 105*n*, 107  
     trichloride, 109, 446  
 Phosphotungstic acid, 374  
 Photographic chemicals, 6, 127, 223, 253, 257, 260, 266, 446, 485, 497, 527  
 Photography, 5  
 Phthalein dyes, 358  
 Phthalic acid, 358, 441, 469, 532  
     anhydride, 41, 45-46, 134, 208, 219-20, 222, 358, 429, 441, 447, 461-2, 532  
     glyceride, 208, 358  
 Phthalimide, 446  
 Phylloxera, insecticide, 202  
 Physicians, census, 437  
 Physics, 251, 434  
 Physostigmine salicylate & sulfate, 287*n*  
 Phytochemical Laboratory, Bureau of Chemistry, 288*n*  
 Picric acid, 231*n*, 251, 441, 451-2  
 Pigments, 33, 37, 114*n*, 136-7, 190*n*, 221, 223, 265, 301*n*, 355, 363-75, 419, 421, 446, 474, 481, 486, 499, 510, 546  
 . Pilocarpine hydrochloride, 287*n*  
 Pine, 355, 365*n*; oil, 356, 461-2; tar, 414  
 Pine Institute, 356*n*  
 Pineapple juice, citric acid, 269  
 Pitch, 212-3, 218, 232  
 Pittman Act, 339  
 Pittsburgh award, 122*n*  
 Pittsburgh Station, Bureau of Mines, 325*n*, 326*n*, 403  
 Pittsburgh University, 279*n*, 420  
 Pituitary gland hormones, 436  
 Plant foods, *see* Fertilizers  
 Plant lice, insecticide, 202  
 Plasmochin, 286  
 Plasticizers, 96, 109, 165-7, 171, 184, 191-2, 223, 358  
 Plastics & synthetic resins, 4-5, 19, 33, 40*n*, 44, 53, 58, 67, 87, 121, 171, 184, 207-8, 210, 212, 217-8, 222-3, 228*n*, 245, 300, 348-62, 364, 408, 413, 429, 447, 450, 527, 544-5  
 Platinum, 446; catalysts, 41, 68, 68*n*, 70, 91-93, 509  
 Platt's Chlorides, 216*n*  
 Plexigum, 354  
 Plumbago, *see* Graphite  
 Plumbite, 391*n*  
 Poisons, 118, 185, 280; gas, 202, 265, 342; industrial, 214, 439  
 Poland, chemical industry, 13, 58; molasses, 161; tariff, 61*n*  
 Polishes, 158, 200, 443, 449  
 Polyhalite, 325  
 Polymerization, 198, 348, 396  
 Polymers, 348, 391*n*  
 Polyvinyl chloride, 413  
 Ponolith, 37  
 Porcelain, 4, 138  
 Portland cement, 136  
 Portugal, pyrites, 82  
 Potash, 12, 28, 50-52, 54-55, 58-59, 68*n*, 145, 265, 311, 316-7, 322-6, 421*n*, 433*n*, 461-2, 479, 498, 507, 541  
     alum, *see* Alum  
 Potash Law of 1910, 1919 (Ger.), 51, 54  
 Potassium, 18, 446, 486  
     -aluminum sulfate, 446  
     -antimony tartrate, 446, 486  
     bicarbonate, 446, 486  
     bichromate, 446, 461-2, 487, 499  
     bisulfate, 461-2  
     bitartrate, 442, 472, 477  
     bromide, 446, 461-2, 486  
     carbonate, 120, 446, 461-2, 486  
     chlorate, 130-31, 230*n*, 446, 486  
     chloride (muriate), 119, 120*n*, 130-31, 323, 325-6, 447, 461-2, 486  
     chromate, 447, 487



- Potassium citrate, 447  
 compounds, 58, 263, 265, 446-7, 450, 487, 499  
 cyanide, 447, 461-2, 487  
 ferri(o)cyanide, 447, 461-2, 487  
 hydroxide (caustic potash), 119, 230<sub>n</sub>, 447, 461-2, 487  
 iodine, 447, 487  
 muriate, *see* Potassium chloride  
 nitrate, 316, 447, 461-2, 487  
 oxide, 87, 323, 325  
 perchlorate, 447, 486-7  
 permanganate, 447, 463-4, 487  
 phosphate, 102-3, 518  
 -sodium tartrate (Rochelle salt), 447, 463-4, 487  
 sulfate, 325, 447, 463-4, 487-8  
 Potatoes, alcohol, 160; disinfectants, 343  
 Potts medal, 39<sub>n</sub>  
 Poultry feeds, 191, 424, 518  
*Prairie Farmer*, 387  
 Precious stones, 349  
 Prescriptions, 274-6  
 Preston, 41, 197  
 Price cutting, defined, 21<sub>n</sub>  
 Prices, 3, 9, 20-25, 26<sub>n</sub>, 27, 52, 116, 196<sub>n</sub>, 276-8, 287, 300-301, 304-5, 312-4, 326-7, 338-9, 341  
 Priestley medal, 252<sub>n</sub>, 399<sub>n</sub>  
 Princeton University, 37<sub>n</sub>  
 Printing ink, 232, 348, 357, 364, 449  
 plates, 544  
 Prizes & medals, 432, 435  
*Problems of Muscle Shoals* (MacDowell), 320<sub>n</sub>  
 Procaine, 246-7, 287<sub>n</sub>, 447, 484, 532  
 Producer gas, 93  
 Prohibition, 151-68, 185, 282, 294, 423  
 Prohibition Bureau, 153, 156, 159  
 Propane, 195, 209-10, 405-6, 425  
 Proprietary Association, 154, 280  
 Proprietary drugs, 247, 274<sub>n</sub>, 290-91, 303, 449; *see also* Drugs; Medicinals; Pharmaceuticals  
 "Proprietary manufacturer," 274<sub>n</sub>  
 Propyl alcohol, 441, 470  
 compounds, 400  
 selenium, 399  
 Propylene, 184, 193, 195, 269  
 chlorohydrin, dichloride, glycol, 447, 488  
*Prosperity Beckons* (Hale), 215<sub>n</sub>  
 Prussian blue, 474, 546  
 Public debt, 15  
 Public Health Service, 213<sub>n</sub>, 250, 281<sub>n</sub>, 282, 342, 403  
 Publications, chemicals, 432, 437, 439  
 Puerto Rico, butanol, 189<sub>n</sub>  
 Pulp colors, 546  
 Pure Food Law, *see* Food & Drugs Act  
 Pyrethrum, 343  
 Pyridine, 156, 213, 332, 447, 463-4, 488  
 Pyridium, 290  
 2-(3-Pyridyl)-piperidine, 332  
 Pyrites, 31, 67, 67<sub>n</sub>, 72-73, 81-83, 99<sub>n</sub>, 101<sub>n</sub>, 370, 433<sub>n</sub>, 447, 463-4, 488, 514  
 Pyrofax, 195, 195<sub>n</sub>  
 Pyrogalllic acid, 441, 469  
 Pyrogallol, 532  
 Pyroligneous acid, 178<sub>n</sub>, 179, 181, 183  
 Pyrotechnics, 130  
 Pyroxylin, *see* Nitrocellulose  
 Pyrrhotite, 81  
 Pyrrolidines, 332  
 Quartz, 420  
 Quebracho, 421<sub>n</sub>  
 Quicksilver, *see* Mercury  
 Quinaldine, 447  
 Quin-Coco, 278  
 Quinhydrone theory (pigmentation), 137<sub>n</sub>  
 Quinidine, 488  
 Quinine, 12, 284-6, 488; sulfate, 278, 447, 463-4, 488, 499  
 Quinine Convention, 284  
 Quinoline, 447; yellow, 231, 539  
 R salt, 463-4  
 Racephedrine, 540  
 Radio industry, 5-7, 19, 138, 143, 295, 339, 348  
 Radioactive substances, 447  
 Radium, 447, 488  
 Raffinose, 447  
 Rasorite, 145, 271  
 Rationalization, in European industry, 48-63  
*Rats, Lice and History* (Zinsser), 232<sub>n</sub>  
 Raw materials, chemical, 6, 12, 18-19, 29, 35, 275, 296, 304, 429, 431, 440, 441-8  
 Rayon, 6, 29, 33, 38, 53, 56, 58-59, 67-68, 94<sub>n</sub>, 111-2, 114-5, 155, 166, 171, 182<sub>n</sub>, 202, 237, 351, 352<sub>n</sub>, 360<sub>n</sub>, 369<sub>n</sub>, 376-89, 408, 417-8, 449, 449<sub>n</sub>, 450<sub>n</sub>, 510, 514-5, 521, 539, 547  
 Rayon Institute, 388

- Rayon & Synthetic Yarn Association, 388
- Reagents, 127, 223, 257, 259, 267, 350, 394
- Recent Economic Changes*, 46*n*
- Red lead, 371, 447, 459-60, 488, 499, 546
- oil, *see* Oleic acid
- oxide, 372
- Red spiders, control of, 333
- Reducing agents, 131
- Refractories, 29, 136, 139, 421, 523
- Refrigeration, 85, 92, 184, 398*n*, 425-6, 515*n*
- Rennet, 354
- Reparations Commission, 268*n*
- Research, 32, 59, 86, 125, 152, 159, 170, 185, 228-9, 238, 245, 247, 249-52, 267, 275-6, 279-84, 286, 288, 296, 315, 323, 336, 343, 350, 354, 356, 360, 364, 366, 369, 374, 390-91, 395-7, 398*n*, 399-401, 409, 416, 418-9, 422-4, 430-37, 439
- Resinated toners, 374
- Resins, natural, *see* Gums & resins; synthetic, *see* Plastics & synthetic resins
- Resorcinol, 251, 287, 447, 463-4, 488
- Respiratory diseases, chlorine in, 266
- Retort gas, 209
- Revertex process (latex), 412
- Rexall drugs, 276
- Rhamnose, 447
- Rhizoctonia, control of, 343
- Rhodamine B, 538-9
- Rhodamine 6GDN, 539
- Rhodesia, chromite, 143
- Rhodinol, 302, 447
- Rhodium, 92, 447
- Rhuma-Sulphur, 216*n*
- Riboflavin, 191
- Ribose, 447
- Rice hulls, cellulose, 387; furfural, 350
- Rice Institute, 252*n*
- Richards medal, 402*n*
- Road building, 143, 207
- Rochelle salt, *see* Potassium-sodium tartrate
- Rockefeller Foundation, 281*n*
- Rockefeller Institute for Medical Research, 249
- Rodenticides, 43, 138, 202, 337
- Romance of Research: The Story of Ethyl Gasoline* (Carpenter), 260*n*
- Roofing materials, 207, 421
- Roots, medicinal, 247
- Rosin, 350, 355-7, 364, 419, 429, 447, 463-4, 489, 499-500
- Rotenone, 343
- Rouge, 295, 303
- Rubber, 4, 6, 43, 53, 73, 115, 121, 136*n*, 189*n*, 210, 214, 221, 223-4, 368-9, 409-14, 430, 502, 514, 521, 548; cement, 449
- Ruhr Coal Research Institute, 433
- Rumania, 15; chemical industry, 58
- Russia, 62; amyl compounds, 191; chemical trade, 59; iodine, 266; nitrogen, 90; phosphate rock, 100*n*; pine tar, 414; tariff, 61*n*
- Rustproofing, 108
- Rutgers University, 286*n*, 438*n*
- Ruthenium, 447
- Saccharides, 447, 489
- Saccharin, 254, 259, 304, 447, 463-4, 489, 532
- Safety glass, 300, 420
- Safety practices, 27
- Safranine, 229, 231
- Safrole, 447
- St. Andrews University, 433
- Sal ammoniac, *see* Ammonium chloride
- Sal soda, 118, 447, 463-4, 489, 500, 520
- Salesmen's Association of the American Chemical Industry, 23, 25, 26*n*, 27, 437, 503
- Salicin, 447, 489
- Salicine black U, 529
- Salicylaldehyde, 305*n*
- Salicylallylamido-*o*-acetic acid, 250
- Salicylic acid, 254-5, 441, 451-2, 469, 532
- Salol, 255, 447, 489, 532
- Salt (sodium chloride), 18, 50, 74, 76*n*, 101*n*, 114, 121-2, 128, 131, 137, 221, 264-6, 272, 326, 339, 447, 449, 490, 500, 548
- cake, 101*n*, 128-9, 419, 447, 463-4, 491, 522
- Saltpeter, *see* Potassium nitrate (crude); Sodium nitrate
- Salts, 34, 170*n*, 289*n*
- Salvarsan, 131, 246*n*, 489
- Salyrgan, 249
- Sanitation, with chlorine, 119*n*, 120, 125
- Santicizers, 221
- Santonin, 447
- Satin white, 447, 489
- Sausage casing, viscose, 353, 425
- Sawdust, cellulose, 349*n*
- Scandinavia, phosphate rock, 100

- Schoellkopf medal, 352*n*  
 Scholarships, *see* Fellowships & scholarships  
*Schultz Index*, 239  
 Schultz process (chrome tanning), 33  
 Science, awards, 435  
 Scio College, 279*n*  
 Scott medal, John, 268*n*, 393*n*  
 Sea water, bromine, 261-4, 400; magnesium, 140  
 Sealing products, 352, 413  
 Searles Lake, potash-borax, 144-5, 272, 323-4  
 Seaweed, *see* Kelp  
 Sebacic acid, 358  
 Sedatives, 127, 247-8, 260  
 Seed disinfectants, 38, 332, 343  
 Selenium, 204*n*, 447, 489  
     compounds, 399  
     oxychloride, 204, 399  
 Selling, 7; chemicals & drugs, 28, 115-7, 181-2, 233-7, 274-8, 288, 291, 344-5, 355-6; contract, 22-26  
 Semesan, 323, 343  
 Senate Special Committee Investigating the National Defense Program (1944), 140*n*  
 Seraceta, 384  
 Serbia, tariff, 61*n*  
 Serums, 289*n*  
 Setacyl dyes, 237  
 Sewage, disinfection, 125; fertilizer from, 318  
 Shales, oils, 392*n*; potash, 421*n*  
 Shanks process (nitrate), 315  
 Sheep dip, 447, 489  
 Sheeting, cellulose, 351-3  
 Shellac, 232*n*, 544  
 Sherman Anti-Trust Act, 7, 9, 286  
 Shingles, from coal tar, 207  
 Shoe industry, coated fabrics, 353  
 Sicilian Consortium, 78-79  
 Sicily, *see* Italy  
 Siennas, 447, 489  
 Silica, 115, 131, 420, 447; gel, 70-71, 394  
 Silicates, 143-4  
 Silicic acid, 469  
 Silicofluorides, 341  
 Silicon, & alloys, 442, 447; esters, 368  
     -aluminum, 447  
     tetrachloride, 202  
 Silk, 96, 376, 385, 417; *see also* Rayon  
 Silver, 89, 250, 339*n*, 340, 371, 447  
     arsphenamine, 250  
     nitrate, 463-4  
     salts, 254  
     Sizes, 419, 449  
     Sleeping sickness, remedies, 249  
     Smoke screens, 202  
     Smokeless powder, 188  
     Sniafil, 417  
     Snow's Liniment, 216*n*  
     Soap, 5, 23, 111, 115, 118, 131, 144, 156, 158, 203, 294, 341, 366, 434, 449, 450*n*, 521, 548; *see also* Detergents  
     Soapstone, 447  
     Societies, scientific, 153, 436-7  
     Society of Chemical Industry, 252*n*, 439*n*  
     Soda, hydrated, *see* Sal soda  
     ash, *see* Sodium carbonate  
     Sodas, 144, 521  
     Sodium, 114, 447; chlorine cell, 119  
         acetate, 305*n*, 447, 489  
         aluminate, 131  
         -aluminum fluoride, *see* Cryolite  
         amide, 86  
         -ammonium phosphate, 518  
         arsenate, 447, 490  
         arsenic compounds, 543  
         arsenite, 334, 334*n*, 337, 463-4, 543*n*  
         arsphenamine, 250  
         benzoate, 10*n*, 447, 463-4, 490, 532  
         bicarbonate, 25, 102, 118, 447, 463-4, 490, 500, 520  
         bichromate, 377, 447, 463-4, 490, 500, 548  
         bisulfate, 128, 490  
         bisulfites, 447, 490  
         borate, *see* Borax  
         bromide, 447, 463-4, 490  
         carbonate (soda ash), 10, 25, 78*n*, 30, 102, 111-3, 114*n*, 115-8, 128, 131, 144, 264, 272, 447, 463-4, 489, 500, 515, 520-21, 548  
         chlorate, 130-31, 447, 490  
         chloride, *see* Salt  
         chromate, 447, 490, 500  
         citrate, 447  
         compounds, 28, 127-31, 265, 324, 450, 490, 500, 543  
         cyanide, 43, 88-89, 342, 412*n*, 447, 463-4, 489, 500  
         ferrocyanide, 43, 447, 463-4, 490  
         fluoride, 447, 490  
         fluosilicate, 337, 341  
         formate, 447, 490  
         hydrosulfite, 131, 447, 490  
         hydroxide, 10, 19, 25, 29, 98, 111-9, 121-3, 191, 217, 230*n*, 377, 404, 447, 463-4, 491, 500, 520-21, 535-6, 548  
         hypochlorite, 230*n*

- Sodium hyposulfite, *see* Sodium thio-sulfate  
 nitrate, 18*n*, 31, 37, 50, 71, 71*n*, 85, 86*n*, 87, 90-91, 93-94, 101*n*, 127-8, 220, 267, 311-6, 447, 463-4, 491, 515*n*, 548  
 nitrite, 14, 86, 92, 123, 129-30, 220, 447, 463-4, 491  
 oleate, 98  
 oxalate, 447  
 phosphates, 96, 101-3, 108, 325, 448, 463-4, 491, 516, 518  
 polysulfide, 410  
 salicylate, 255, 463-4, 533  
 sesquicarbonate, 448  
 silicate, 143, 377, 448, 463-4, 491, 500, 548  
 silicofluoride, 341, 448, 491  
 sulfates, 101*n*, 102*n*, 128-9, 131, 136*n*, 377, 418, 448, 463-4, 491, 500, 522, 548; *see also* Niter cake; Salt cake  
 sulfhydrate, 137, 448, 491  
 sulfide, 101*n*, 129, 131, 448, 465-6, 491  
 sulfite, 102, 224, 448, 465-6, 491  
 sulfoxylate, 448, 491  
 thiosulfate (hyposulfite), 101*n*, 102, 129, 448, 463-4, 492  
 Sodium-lead process (tetraethyl lead), 400, 402  
 Soils, research, 281  
 Soils Bureau, 104, 325*n*, 438  
 Solantine dyes, 231  
 Solros, 356  
 Solvay process (alkalies), 128  
 Solvents, 42*n*, 121, 156, 157*n*, 158, 160, 165-7, 171, 178, 182, 184, 187-206, 210, 214, 228*n*, 233, 267, 348, 350-51, 358, 374, 391, 394, 404-6, 433, 546  
 Solvents Institute, 204  
 Sorbitol (sorbite), 39, 448  
 Sorrel cement, 139  
 Sound pictures, 5  
 "Sour dirt," 76*n*  
 South, arsenic, 335-6; chemical plants, 29; minerals, 420-21; naval stores, 355, 431; paper, 128, 418-9; power, 43*n*, 336; rayon, 29, 381; tanning extracts, 421; tung oil, 11*n*, 364*n*; wood chemicals, 174, 178, 180  
 South Africa, chromite, 143; phosphate rock, 100  
 South America, 15; bauxite, 131-2; chemical trade, 11*n*, 59  
 South Carolina, insecticides, 337; phosphate rock, 98  
 South Pacific islands, phosphates, 100-101  
 Southern California University, 102  
 Southern Fertilizer Association, 328  
 Southern Research Institute, 336*n*  
 Southern States Industrial Council, 107*n*  
 Soybean oil, 363, 461-2  
 Spain, chemical trade, 58; lead, 371; mercury, 269; pyrites, 31, 82, 370; tariff, 61*n*  
 Spanish brown, 474  
 Spark plugs, andalusite for, 136  
 Spearmint oil, 461-2  
 Spectrophotometry, of dyes, 238  
*Spirit of Enterprise* (Queeny), 43*n*  
 Spodumene, 271  
 Sprague Memorial Institute, 251*n*  
 Sprays, oil, 341, 343  
 Spruce, 418; turpentine, 201  
 SRA dyes, 237  
 S.S. Ethyl, 262  
 S.S. Lake Harminia, 262  
 S.S. Lützow, 313-4  
 S.S. Munardan, 421*n*  
*Stain Technology*, 238*n*  
 Stains, 158, 254, 374*n*, 443, 449, 497; biological, 238, 253  
 Standards, chemical & drug, 238-9, 275, 279, 374, 438; textile, 417-8  
 Standards Bureau, 12*n*, 238, 344, 417, 421-3, 438  
*Standards Yearbook*, 438  
 Stannous chloride, 351, 448, 493  
 Starch, 127, 160, 191, 349*n*, 422  
 State Department, 7, 14, 281*n*  
 Statistics, chemical, 9-10  
 Stearates, 271  
 Stearic acid, 414, 422, 441, 451-2, 469, 495  
 Steatite, 448  
 Steel, 108; alloy, 41, 92, 442, 535; *see also* Iron & steel industry  
 Stereochromic painting, 143  
 Sterling Chemistry Laboratory, 434-6  
 Stock exchanges, chemical companies, 35  
 Stock feeds, 160, 191, 267, 318, 328, 350*n*, 424, 517, 518, 544  
 Straw, bleach, 131; cellulose, 387  
 Strontianite, 492  
 Strontium, alloys, 442  
   carbonate, 448, 492  
   nitrate, 448, 465-6, 492  
   oxide, 448, 492  
   sulfate, 492

- Strychnine, 337, 448, 492  
  salts, 448, 492  
  sulfate, 465-6, 492  
Styrol resins, 354  
Subox, 371  
Substitution, of drugs, 276-9  
Succinic acid, 358, 358*n*  
Sugar, 39, 108, 127, 131, 160-62, 166,  
  288, 349*n*, 419, 422-3, 425  
Sugar Laboratory, Bureau of Chemis-  
  try, 386*n*  
Suida process (acetic acid), 178-9, 181,  
  184  
Sulfa drugs, 249  
Sulfanilic acid, 441, 533  
Sulfarsphenamine, 249  
Sulfate pulp industry, 128-9, 418  
Sulfated alcohols, 422  
Sulfates, 115, 522  
Sulfite pulp industry, 201, 306, 386*n*,  
  418, 422  
Sulfonamides, 221  
Sulfonation, of benzene, 208, 214, 217  
Sulfur, 18, 31, 51, 60, 67-68, 71-82,  
  129, 134, 176, 272, 341, 367, 433*n*,  
  448, 465-6, 492, 501, 513-4, 548;  
  dyes, 131, 229, 233, 514  
  black, 229, 448, 533  
  brown, 533  
  chloride, 122, 202, 465-6  
  compounds, 134, 260, 391  
  dioxide, 68, 71-72, 81, 231, 394, 405,  
  425, 465-6  
  oxychloride, 399  
  trioxide, 68  
Sulfuric acid, 10, 17-18, 19, 29, 31, 36,  
  58, 67-73, 81-82, 90, 101*n*, 102*n*,  
  106*n*, 112, 121, 128, 136*n*, 182, 193,  
  272, 287, 318, 327-8, 349*n*, 365*n*,  
  367, 370, 377, 382, 391*n*, 394, 404,  
  441, 449, 449*n*, 451-2, 509-10, 514,  
  548; chamber, 68*n*, 70-72, 85, 509,  
  510-12, 515*n*: contact, 33, 41, 45-  
  46, 67-72, 377, 509, 510, 513  
  ether, *see* Ether  
Sulfuryl chloride, 121, 224  
Sulphur Mine (La.), 76  
Sun red, 301*n*  
Superphosphate, 71*n*, 72, 97, 99, 101-2,  
  105-7, 317-8, 326-8, 341, 465-6,  
  501, 517, 518-19, 541  
Supreme Court decisions, 8, 13-14, 240-  
  41, 277-8, 282, 411  
Surinam, bauxite, 132  
Swarthmore College, 39*n*, 240  
Sweden, arsenic, 338; nitrogen, 313  
Switzerland, chemical industry, 13-14;  
  dyes, 56*n*, 59-60, 236; perfumes,  
  297; pharmaceuticals, 248; rayon,  
  382  
Sylphrap, 353  
Sylvinite, 326  
Symposiums & conferences, chemical,  
  432-4  
Syntans, 421  
Synthetic Organic Chemical Manufac-  
  turers' Association, 10*n*, 11*n*, 60,  
  153*n*, 184, 234, 238-9, 290*n*, 549  
Syphilis, remedies, 249-50  
Syracuse University, 70*n*  
Syrup of Figs, 247*n*  
  
Tablets, 279, 287  
*d*-Tagatose, 448  
Talc, 421, 448  
*d*-Talose, 448  
Tallow, 449  
Tankage, 465-6  
Tankcars, for chemicals, 94, 125  
Tanks, rubber-lined, 413  
Tanners' Council of America, 422  
Tannic acid, 441, 451-2, 469  
Tanning, 5, 33, 431; materials, 421-2,  
  444, 448-9, 490, 492, 497, 501, 527  
Tantalum, 448; alloys, 442  
Tar, 173, 178*n*, 184, 211, 217-9, 414,  
  443, 457; *see also* Coal tar; Creosote oil  
Tariff, chemical, 51, 61-62, 94, 100, 109,  
  129-30, 138-9, 143, 163, 172-3, 175-  
  7, 182, 184, 215-6, 218-9, 227, 230,  
  239, 248, 268-71, 286-7, 295-7, 299  
  317*n*, 338-42, 353, 370, 414  
Tariff of 1913 (Underwood), 268*n*  
Tariff of 1922 (Fordney-McCumber),  
  3, 13-14, 61-62, 218, 239, 268-9,  
  295-6  
Tariff of 1930 (Hawley-Smoot), 317*n*,  
  338, 441-8  
Tariff Commission, 13-14, 94, 130, 138-  
  9, 173-5, 216, 218, 239, 248, 341-2  
Tarkio College, 436*n*  
Tartar, 442  
  emetic, 448, 492  
Tartaric acid, 102, 358, 358*n*, 441, 451-  
  2, 469  
Tartrates, acid, 102-3  
Tartrazine, 231  
Taxes, 15, 151-2, 155, 160  
Taylor medal, 268*n*  
Tea Act, 281  
Tea waste, caffeine, 286, 286*n*  
Tear gas, 439

- Technical Association of the Pulp & Paper Industry, 418<sub>n</sub>  
 Tellurium, 204<sub>n</sub>; compounds, 399  
 Tenite, 351  
 Tennessee, barytes, 136; chemical plants, 29; gypsum, 421; phosphate rock, 97-98; pyrites, 81; rayon, 29, 378, 381; wood chemicals, 174  
 Tennessee Agricultural Experiment Station, 316, 341  
 Tennessee Valley Authority (TVA), 56, 106, 320<sub>n</sub>  
 Terpene alcohol, 298<sub>n</sub>  
 Terpin hydrate, 448, 492  
 Terpineol, 301<sub>n</sub>, 302, 448, 465-6, 471, 533  
*Testing for Metallurgical Processes* (Barr), 98<sub>n</sub>  
 Tetrabromophenolphthalein, 288  
 Tetrachloroethane, 199-200, 448, 492  
 Tetrachlorophthalic acid, 441  
 Tetraethyl lead, 5, 36, 38, 120, 134, 204, 213, 260, 260<sub>n</sub>, 261<sub>n</sub>, 263-4, 390-91, 395-6, 398<sub>n</sub>, 400-404  
     tin, 400  
 Tetrahydronaphthalene, 200  
 Tetrahydronaphthol, 200  
 Tetralin, 200  
 Tetralol, 200  
 Tetramethyldiaminobenzophenone, 448  
 Tetramethyldiaminodiphenylmethane, 448  
 Texas, carbon black, 415; gasoline, 416<sub>n</sub>; helium, 195; potash, 322, 325-6; rice wastes, 387; sulfur, 77  
 Texas Cotton Seed Crushers' Association, 431<sub>n</sub>  
 Texas fever, 337  
 Texas Technological College, 438<sub>n</sub>  
 Texas University, 324<sub>n</sub>, 325<sub>n</sub>, 326, 438<sub>n</sub>  
 Textile Alliance, 240, 539  
 Textile Economics Bureau, 382<sub>n</sub>  
 Textiles, 4, 6, 19-20, 46, 68, 94<sub>n</sub>, 112<sub>n</sub>, 113, 115, 119, 122<sub>n</sub>, 131, 144, 182<sub>n</sub>, 198, 221, 227, 231, 356, 368, 377, 377-81, 385, 417, 430, 502, 510, 514, 520<sub>n</sub>, 521; coated, 6, 39, 348, 351, 353, 412, 417  
 Theobromine, 286-7, 448, 492  
 Thinners, 158, 201, 214, 223  
 Thiocarbanilide, 410, 448, 465-6, 493, 533  
 Thiocarbo-*p*-toluidine, 410  
 Thiocyanates, aliphatic, 323, 343  
 Thioindigo dyes, 228  
 Thiokol, 409  
 Thionyl chloride, 224  
 Thiosalicylic acid, 441  
 Thorium, 448; alloys, 442  
     nitrate, 448, 493  
     oxide, 448, 493  
 Thylox process (sulfur), 81  
 Thyme oil, 298<sub>n</sub>  
 Thymol, 298<sub>n</sub>, 299, 302, 304, 448, 465-6, 493  
 Ticks, remedies, 337  
 Tile, composition, 210  
 Timber, 19  
 Tin, 58, 448, 465-6  
     chloride, 58; *see also* Stannous chloride  
     compounds, 58, 448, 493  
     -lead phosphate, 417  
     oxide, 421  
     tetrachloride, 417, 448, 465-6, 493  
 Tinctures, 274  
 Tires, 59, 409, 412, 412<sub>n</sub>, 414, 426<sub>n</sub>  
 Titanium, 136<sub>n</sub>, 397-9, 371, 448; alloys, 442  
     dioxide, 367-9, 421, 465-6  
     nitride, 368  
     -potassium oxalate, 448, 493  
     tetrachloride, 202  
 Titanox, 136<sub>n</sub>, 137  
 Titanox-A, -B, -C, 367  
 Titanox-L, 367<sub>n</sub>  
 TNT, 398, 448  
 Toilet goods, *see* Cosmetics  
 Tolidine, 448, 493  
 Toluene, 31, 68, 201, 207, 209, 213-4, 220, 357, 393, 448, 465-6, 493, 534  
 Toluenesulfochloride, 448, 493  
 Toluenesulfonamide, 448  
     *p*-Toluenesulfonanilide, 221  
 Toluidine, 233, 448, 465-6; *o*-, 214, 217, 465-6, 533; *p*-, 214, 465-6, 533  
 Tolylenediamine, 448; *m*-, 533  
 Toners, 301<sub>n</sub>, 374  
 Tonka bean, 305<sub>n</sub>  
 Tooth pastes, 254, 295  
 Toronto University, 81  
 Tracer bullets, 140  
 Trade, chemical, 13, 31  
 Trade agreements, unilateral, 62  
 Trade associations, 9, 60  
 Trade names, 246, 247<sub>n</sub>, 418  
 Trade Practice Conferences, 344  
 Trade practices, 23, 326, 329, 437  
 Trade wastes, fertilizer from, 318  
*Traffic Library*, 44<sub>n</sub>  
 Transformer oils, 405  
 Treasury Department, 8, 10<sub>n</sub>, 14-15, 108-9, 152-3, 155-6, 158-9, 173, 239, 250, 280<sub>n</sub>, 281, 283, 339<sub>n</sub>

- "Tri," 199-200  
 Triacetin, 465-6  
 Tribromoaniline, 261-2  
 Tribromophenol, 448, 493  
 Tributyl phosphate, 96  
 Tricalcium phosphate, 99<sub>n</sub>, 101, 105<sub>n</sub>, 516, 518  
 Trichloroacetic acid, 200  
 Trichloroethane, 200  
 Trichloroethylene, 199-200, 425, 448, 493  
 Trichloronitromethane, 342<sub>n</sub>  
 Trichlorophenol, 224  
 Tricresyl phosphate, 96, 109, 351, 465-6  
 Triethanolamine, 198  
 Triethylene glycol, 198,  
 1, 3, 7-Trimethylxanthine, 286-7  
 Trinitrophenol, *see* Picric acid  
 Trinitrotoluene, *see* TNT  
 Trinity College, 434  
 Triphenyl phosphate, 96, 109  
 Triphenylmethane dyes, 233  
 Triple superphosphate, *see* Superphosphate  
 Trisodium phosphate, 96, 101-2, 325, 463-4, 516, 518  
 Trona, 102, 118  
 Trusts, 32-35, 48-63  
 Trypanocides, 249  
 Tryparsamide, 249  
 Tsetse fly, 249  
 Tulsa University, 393<sub>n</sub>  
 Tung oil, 11<sub>n</sub>, 198, 357, 363-6, 461-2, 484, 545-6  
 Tungsten, 141<sub>n</sub>, 448; alloys, 448  
     carbide, 448  
 Tungstic acid, 447  
 Tunis, bromine, 262; phosphate rock, 99-100  
 Turbine oils, 405  
 Turkey red oil, 461-2  
 Turmeric, 448, 493  
 Turpentine, 187, 200, 355-6, 429, 448, 465-6, 493, 501  
  
 Ultramarine, 232, 373<sub>n</sub>, 493; blue, 448  
 Umbers, 448, 493-4  
 Underwood Tariff (1913), 268<sub>n</sub>  
 Uniform Sales Contract for Chemicals, Joint Committee, 23, 502-6  
 United States, chemical trade, 17-19  
 U. S. Chamber of Commerce, 9, 27  
 U. S. Nitrate Plant No. 1, 93<sub>n</sub>, 318, 320-21  
 U. S. Nitrate Plant No. 2, 93<sub>n</sub>, 318-9  
 U. S. Pharmacopoeia, 137<sub>n</sub>, 247, 270<sub>n</sub>, 274<sub>n</sub>, 276, 279<sub>n</sub>, 299  
  
 U. S. Rubber Administration, 413<sub>n</sub>  
 U. S. toners, 301<sub>n</sub>  
 "Universal solvent," 399  
 Universities, chemical research, 252, 432, 434  
 University College, London, 70<sub>n</sub>, 433  
 Unsaturated groups, 198  
 Uranium, 448; alloys, 441  
     oxide, 448  
 Urea, 53, 85, 87, 317<sub>n</sub>, 318-9, 448, 465-6, 494, 541; plastics, 44, 354  
 Utah, sodium sulfate, 128  
  
 Vaccines, 289<sub>n</sub>  
 Valeric acid, 441, 469  
 Vanadates, 68, 68<sub>n</sub>  
 Vanadic acid, 68, 448  
 Vanadium, 448; alloys, 442; catalyst, 41, 45, 67-70, 510-11  
     carbide, 448  
     pentoxide, 68-69  
 Vanderbilt University, 324<sub>n</sub>, 403<sub>n</sub>  
 Vandyke brown, 474  
 Vanethal, 306  
 Vanilla, 302, 304-5  
 Vanillin, 302, 302<sub>n</sub>, 304-6, 418, 448, 465-6, 494, 533  
 Varnishes, 11, 94<sub>n</sub>, 158, 166, 182<sub>n</sub>, 187, 200<sub>n</sub>, 201, 232, 354-5, 357-8, 360, 364, 366, 368, 373, 374<sub>n</sub>, 449, 514  
 Vassar College, 434  
 Vat dyes, 131, 134, 208, 219-21, 228, 230<sub>n</sub>, 231, 237  
 Vegetables, arsenic effect, 338  
 Verdigris, 444, 494  
 Vermilion, 465-6; reds, 448, 494  
 Veronal, 246-8  
 Versailles Treaty, 323  
 Vinegar process (acetic acid), 190  
 Vinyl alcohol, 441  
     chloride, 122, 198  
     resins, 122, 198  
 Vinylite, 198  
 Virginia, pyrites, 81; rayon, 29, 381  
 Virginia Polytechnic Institute, 421  
 Viscose rayon, 38, 202, 351, 376-7, 379-84, 386, 547  
     casing, 353, 425  
     sheeting, 351  
 Vitamins, 190<sub>n</sub>, 275, 424; B, 193<sub>n</sub>, 275, 424  
 Volstead Act, 151-2, 155, 158-60, 162, 423; *see also* Prohibition  
 Vulvalox process (rubber), 413  
 Vulcanization, 221, 410-12

- Wall Street Journal*, 28  
 Walnut oil, 373  
 War Department, 34, 90, 140<sub>n</sub>, 188, 197, 238, 378  
 War Finance Corp., 40<sub>n</sub>  
 War gases, 202, 265, 342  
 War Industries Board, 73, 322<sub>n</sub>  
 Washing soda, 500  
 Washington (state), calcium arsenate, 335; sodium sulfate, 128  
 Washington Naval Conference, 15  
 Washington University, St. Louis, 42<sub>n</sub>, 43<sub>n</sub>, 288; Seattle, 413<sub>n</sub>, 436<sub>n</sub>  
 Wastes, industrial, 318, 418-9, 433<sub>n</sub>  
 Water, 170, 176-7, 425; treatment, 96, 119, 125, 131, 266, 339, 521  
     gas, 93, 176, 209, 405  
 Waxes, 121, 404-5  
 Webb-Pomerene Act, 60, 78-79, 340, 355, 371, 416  
 Weed killers, 131, 200<sub>n</sub>, 334, 334<sub>n</sub>  
 Welding, 41  
 Wellcome medal, 288<sub>n</sub>  
 Wellesley College, 233<sub>n</sub>  
 West, alkalis, 118; beet sugar, 423; carbon black, 415; sulfur, 79-80  
 West Coast, agar, 424; alkalis, 118; chemical plants, 28; citrus industry, 269; electrolytic industry, 124-5  
 West Indies, phosphate, 100, 106<sub>n</sub>  
 West Virginia, brines, 265; chemical plants, 29; natural gas, 415; wood chemicals, 174, 181  
 West Virginia University, 421, 438  
 Western Reserve Medical School, 251  
 Western Society of Engineers, 397<sub>n</sub>  
 Wetherill furnace, 369  
 Wetting agents, 6, 233  
 Whisky, *see* Prohibition  
 Whitar dyes, 232  
 White arsenic, 333-8, 448, 453-4, 467-8  
     lead, 178, 369, 371, 448, 459-60, 494, 501, 546  
 Whiting, 372, 443, 465-6, 494, 546  
 Williams College, 252<sub>n</sub>, 433  
 Williamstown Institute of Politics, 433  
 Wilson Act, 286  
 Wilson Dam, Muscle Shoals, 322  
 Wine lees, 160, 442  
 Wisconsin, wood chemicals, 175, 181  
 Wisconsin University, 189<sub>n</sub>, 204, 283<sub>n</sub>, 284, 288<sub>n</sub>, 318, 399, 434, 434<sub>n</sub>  
 Wood, 169<sub>n</sub>; alcohol, *see* Methyl alcohol; chemicals, 29, 53, 127, 155, 169-86, 201, 449, 450<sub>n</sub>, 525; preservatives, 124, 207, 211-2, 337; pulp, 20, 386-7, 520<sub>n</sub>; rosin, 350, 355-7  
 Wood Chemical Institute, 185  
 Woodbury Facial Soap, 294  
 Wool, 122, 233; synthetic, 417  
 World War I, 9, 22, 245<sub>n</sub>; debts, 15-16  
 World War II, 43<sub>n</sub>, 132, 140<sub>n</sub>, 141<sub>n</sub>, 171<sub>n</sub>, 185<sub>n</sub>, 189<sub>n</sub>, 196<sub>n</sub>, 197, 286<sub>n</sub>, 324<sub>n</sub>  
 Wrapping film, 351-3  
 Wytek Fibre, 386  
 X-ray, 288, 433  
 Xanthates, 414, 533  
 Xenol, 535  
 Xylene, 209, 213-4, 357, 448, 465-6, 494  
 Xylenols, 217  
 Xylidine, 448, 465-6, 494  
 Xylose, 350<sub>n</sub>, 423, 448  
 Yale University, 213, 251-2, 313, 320, 399, 403<sub>n</sub>, 434, 435<sub>n</sub>, 436, 438<sub>n</sub>, 539  
 Yeast, 423-4, 449  
 Yellow eosin, 238  
     oxide, 372  
 Yerba santa, 278  
 Yugoslavia, 15; chemical plants, 59; nitrogen, 312  
 Zeolite, 69  
 Zinc, 19, 60, 67<sub>n</sub>, 72, 82, 102, 339, 369-71, 448, 514  
     chloride, 104, 448, 465-6, 494  
     ethyl, 398, 400  
     oxide, 37, 355, 355<sub>n</sub>, 368-70, 377, 414, 448, 465-6, 501, 546, 548  
     salts, 58  
     sulfate, 448, 465-6, 494  
     sulfide, 136, 445, 448, 494  
 Zinc Export Association, 371  
 Zirconium, 448; alloys, 442  
     oxide, 421





